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Proceedings of the Defense Nuclear Agency Conference on Arms Control and Verification Technology (ACT), 1-4 June 1992

Jerry Van Keuren
Linda Fisher
Kaman Sciences Corp.
Engineering Sciences Division
2560 Huntington Avenue
Suite 200
Alexandria, VA 22303

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Jerry Van Keuren, Linda Fisher

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The first Defense Nuclear Agency Conference on Arms Control and Verification Technology provided an international forum for over 200 individuals from the arms control verification technology and national security communities for discussion on the future of arms control verification and technology developments. Papers were presented in the following sessions: Future Arms Control Initiatives, Interface between Intelligence and Arms Control, Lessons Learned, Proliferation in a Changing World, Technologies - Roles and Applications, and Economics of Arms Control. Plenary sessions were held for general presentations on the future role of verification technology, and negotiating and implementing verification measures.

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TABLE OF CONTENTS

SESSION I

Future Arms Control Initiatives

Chairman
Ambassador M. Glitman
former Chief, U.S. Delegation to the INF Negotiations

Conference on Arms Control and Verification Technology
1-4 June 1992
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Verification of a Future Convention Prohibiting Radiological Weapons

A. Turrentine
The Harris Group

Prepared for:
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Verification of a Future Convention Prohibiting Radiological Weapons

by Archelaus R. Turrentine

Introduction

The potential for using the radioactive emissions from radioactive material, in the absence of a nuclear explosion, as the damage-causing agent in a weapon was recognized from the onset of the nuclear era. However, apart from early enthusiasm in the 1940's and feasibility studies in the 1950's, there has been little openly displayed interest since then in developing this class of weapons. Radiological weapons (RW) currently exist only as a concept, and no nation is known to hold them in its arsenal or to be seeking to acquire them. However, they are included in the long-established, internationally accepted definition of "weapons of mass destruction." As the options are removed or narrowed for states to acquire other types of weapons of mass destruction, interest in acquiring RW may be stimulated unless legally binding commitments are undertaken to place RW clearly out of bounds.

Background

The notion of a special category of weapons identified as "weapons of mass destruction" was introduced on November 15, 1945, in a joint declaration by the Heads of Government of the United States, United Kingdom, and Canada. While the focus of this declaration was to promote the protection of atomic energy information, it also recommended that a UN Commission be established to make specific proposals, inter alia, "for elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction."

On August 12, 1948, the UN Commission for Conventional Armaments adopted, despite Soviet opposition, the following definition for "weapons of mass destruction":

> "weapons of mass destruction should be defined to include atomic explosive weapons, radioactive material weapons, lethal chemical and biological weapons, and any weapons developed in the future which have characteristics comparable in destructive effect to those of the atomic bomb or to other weapons mentioned above."

Many years later, the Soviet Union accepted this definition which is now the universally agreed definition of weapons of mass destruction. While the Conference on Disarmament in Geneva has continued to keep the issue of new weapons of mass destruction under review for more than a decade, no additional weapons have been designated "new weapons of mass destruction" under this definition.

Several important international treaties contain provisions that deal with weapons of mass destruction, which, of course, include radiological weapons.

For example, in the 1967 Outer Space Treaty, the States Parties "undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner."

In the 1972 Seabed Treaty, the States Parties undertake not to emplant or emplace on the seabed any "nuclear weapons or any other types of weapons of mass destruction as well as structures, launching installations or any other facilities specifically designed for storing, testing or using such weapons."

In the unratified SALT II Treaty, the prohibition of emplacing nuclear weapons on the seabed was extended to territorial and inland waters, and each party undertook not to develop, test, or deploy systems for placing into Earth orbit nuclear weapons or any other kind of weapons of mass destruction, including fractional orbital missiles.

The START Treaty picked up a slightly modified version of this language, again recognizing the prohibition of emplacing nuclear weapons on the seabed and extending it to territorial and inland waters, and stating "each party undertakes not to produce, test, or deploy systems, including missiles, for placing nuclear weapons or any other kinds of weapons of mass destruction into Earth orbit or a fraction of an Earth orbit."

At the 1989 Seabed Treaty Review Conference, the United States, United Kingdom, and Soviet Union each stated that it had not emplaced any nuclear weapons, or any other weapons of mass destruction on or under the seabed, or in territorial or inland waters, and had no intention to do so.

In sum, the following constraints already apply to RW:

--radiological weapons are included in the definition of weapons of mass destruction.

--as weapons of mass destruction, radiological weapons are prohibited from being stationed in outer space.

--as weapons of mass destruction, radiological weapons are prohibited from being emplaced on or under the seabed.

--the United States and former Soviet Union have declared that they have not placed and have no intention of placing weapons of mass destruction, which would include radiological weapons, on or under territorial and inland waters.

--the United States and former Soviet Union undertake in the START Treaty not to produce, test, or deploy systems for placing weapons of mass destruction, which would include radiological weapons, into Earth orbit or a fraction of an Earth orbit.

Curiously, there is no generally accepted definition of what a radiological weapons is. However, it should be noted that there is no generally accepted treaty definition of what a nuclear weapon is either.

Radiological Weapons

Clearly those who originally created the category of radiological weapons did not intend to include nuclear explosives within the category since nuclear weapons were assigned their own, separate category. However, there were no clearly understood criteria that would permit unambiguous identification of a radiological weapon should one suddenly appear.

In a program of General and Complete Disarmament submitted in 1961 by the United States to the UN General Assembly, it was specified that a chemical, biological, radiological (CBR) experts commission be established for the purpose of "examining and reporting on the feasibility and means for accomplishing the verifiable reduction and eventual elimination of CBR weapons stockpiles and the halting of their production." This indicates that at this time the United States considered RW a category of weapons having significant military potential that should not be overlooked, at least in the context of General and Complete Disarmament.

In 1967, Malta introduced a draft resolution in the First Committee of the UN General Assembly which dealt with chemical, biological, and radiological weapons, and called on the Eighteen-Nation Disarmament Committee (one of the predecessors of the current Conference on Disarmament) to consider updating the 1925 Geneva Protocol. The Netherlands introduced a successful amendment to the Maltese draft which deleted the reference to RW.

In 1969, an omnibus resolution on General and Complete Disarmament was adopted by the UN General Assembly, despite the opposition of the United States and most of the Western and Eastern worlds to some of the parts of the resolution. Part C of this resolution addressed radiological warfare and in the preamble said, "aware that radiological warfare may be conducted both by maximizing the radiological effects of nuclear explosions and through the use of radioactive agents independently of nuclear explosions." By introducing the notion of a broad concept of radiological warfare that might involve specially designed nuclear weapons packed with cobalt that "maximize the radiological effects of nuclear explosions" in addition to "the use of radioactive agents independently of nuclear explosions," the entire issue of defining RW, and drawing a distinction between RW and nuclear weapons, became muddled.

In 1970, at the Conference of the Committee on Disarmament (CCD - another of the predecessors to the current Conference on Disarmament), the Netherlands submitted a working paper on radiological warfare. The paper acknowledged the two modes of radiological warfare, and quickly dismissed "salting" nuclear weapons as not offering any military advantages. The paper stated "the trend in nuclear weapons technology is going in the direction of cleaner weapons rather than dirtier ones." With respect to the use of radioactive agents independently of nuclear explosions, the paper concluded that to kill or harm people within a few hours, a radiation dose of at least 1,000 roentgen would be required. The highly radioactive isotopes needed to produce such an intense radiation dose all have short or very short half-lives. The paper concluded that the amount of material required to produce a radiological weapon with prompt effects was simply not feasible, and that producing a radiological weapon with long term effects would have no military benefit. Thus, "possibilities for radiological warfare do exist theoretically, but do not seem to be of much or even of any practical significance."

In commenting on the Netherlands paper, the Swedish representative agreed with the conclusions, saying "to block temporarily a terrain area of ten to twenty square kilometers, the total reactor effect available at present in the world would be required...such a method of warfare would be militarily unattractive."

Shortly, after the U.S. election in November 1976, but before the change of Administration, ACDA Director Fred Ikle presented an initiative on prohibiting RW use to the UN First Committee. He called for the CCD to negotiate a new agreement on RW that would complement the 1925 Geneva Protocol that deals with CW and BW.

After the initial Carter Administration expedition to Moscow in March 1977 to explore the arms control agenda, it was announced that the two sides had agreed, <u>inter alia</u>, at the Soviet's request, to discuss the termination in the capability of waging radiological or chemical warfare. In May 1977, the first in a long series of bilateral discussions on RW was held in Geneva in parallel with CW bilaterals.

In 1978, in paragraph 76 of the Final Document of the First Special Session of the UN General Assembly devoted to disarmament, the importance of pursuing a comprehensive RW ban was recognized. The Final Document stated, "a convention should be concluded prohibiting the development, production, stockpiling and use of radiological weapons." It should be noted that the comprehensive ban called for went far beyond the simple non-use prohibition that had been suggested by ACDA Director Ikle in 1976.

On July 9, 1979, the U.S. and Soviet Representatives to the Committee on Disarmament (the immediate predecessor to the Conference on Disarmament) each presented copies of "Agreed Joint U.S. - USSR Proposal on Major Elements of a Comprehensive RW Treaty." The definition of RW that had been agreed by the two sides was:

> "For the purpose of the Treaty, the term "radiological weapon" means:
>
> 1. Any device, including any weapon or equipment, other than a nuclear explosive device, specifically designed to employ radioactive material by disseminating it to cause destruction, damage or injury by means of the radiation produced by the decay of such material.
>
> 2. Any radioactive material, other than that produced by a nuclear explosive device, specifically designed for employment, by its dissemination, to cause destruction, damage or injury by means of the radiation produced by the decay of such material."

Consideration of RW in the CD

After the end of the CD's 1979 session, late in 1979 the UN General Assembly adopted a resolution requesting the CD "to achieve agreement, through negotiations, on the text of such a (RW) convention." During the first part of its 1980 session, the CD established an Ad Hoc Working Group with a view to reaching agreement on a convention prohibiting the development, production, stockpiling and use of radiological weapons.

In the summer of 1980, CD work on the RW Convention began in earnest. One of the first bones of contention was the definition of radiological weapons that the United States and Soviet Union had proposed. A key sticking point was the explicit exclusion of nuclear weapons. Some members wanted to ban any "intentional" dissemination of radioactive material for hostile purposes. Sweden suggested that the ban also should cover attacks on facilities, such as power reactors or other nuclear fuel cycle facilities, in which large amounts of radioactive material are present and could be released as a consequence of an attack.

In 1981, Israel attacked Iraq's large Tammuz I research reactor in the final stages of construction near Osirak. This event reinforced Swedish interest in providing additional legal protection to "peaceful" nuclear facilities via an RW Convention, and expanded interest by others in such a notion. The United States, together with a number of other countries, objected to expanding the scope of the RW Convention under negotiation to include attacks on nuclear facilities. The pragmatic solution that was acceptable, if not particularly satisfying, to those on both sides of the issue was to take a "two track" approach. The first track, Track A, would deal with "traditional" RW (and proceed with the negotiation of a RW convention along the lines of the U.S. and Soviet proposal) and the second track, Track B, would focus on some appropriate undertaking aimed at providing additional legal protection against attacks on peaceful nuclear facilities.

For the next few years, the CD's work on the RW issues received considerable attention. However, with major proposals on CW being put forward in 1983 and 1984, CD interest and attention were quickly switched to CW negotiations, which involved existing weapons and therefore were considered to be more important and more "glamorous" from an arms control point of view. At the end of the CD session in 1985, the U.S. Representative to the CD expressed concern about the lack of consideration in the RW convention negotiations of explicit verification provisions. There was an implication that the United States might put forward some appropriate ideas on the subject at an early date.

No U.S. initiatives or proposals on RW verification were put forward subsequently in 1986 and none have been put forward since that time.

Nevertheless, each year the CD has reestablished the RW Ad Hoc Committee, with its two tracks, to continue negotiations on RW issues, albeit at a snail's pace.

While it is understandable that arms control politics have kept RW from displacing CW at center stage, it would make a certain amount of sense to be prepared to move ahead on RW when the time is deemed to be appropriate. Indeed, with the fundamental political changes in the world and the significant arms control achievements of recent years, there are no longer any compelling reasons to delay completing a RW Convention. It would be reassuring for the CD to demonstrate that it might be able to "keep two balls in the air at the same time."

There are several approaches that might be considered in repairing, or at least narrowing, the RW verification "gap" that bothered the Reagan Administration in 1986, and presumably, as a matter of principle, i.e., "no additional arms control agreements with no verification provisions," still is a matter of concern to the Bush Administration.

Possible Changes in RW Scope, Verification, and Structure

When the joint U.S. - Soviet RW arms control initiative was originally developed, serious consideration, at least on the U.S. side, was given to including intrusive verification provisions. However, in the final analysis, the potential cost to U.S. security interests from intrusive RW verification procedures for a comprehensive RW ban was deemed greater than the potential security benefits they might provide. For the same type of comprehensive approach, the same conclusion may still hold.

However, for policy reasons, and because of problems that have been experienced with other arms control measures that had no built-in verification, it now seems ill-advised to conclude any arms control measure devoid of effective verification and effective complaints procedures. The following changes might be considered individually, or collectively, in developing proposals to change the scope and structure, and add appropriate verification provisions, to the "traditional" RW convention (Track A) currently under negotiation in the CD. One prerequisite would be to delink Track A from Track B. However, delinking the two would not necessarily require terminating consideration of Track B. If there were the prospect of real progress in actually concluding a meaningful RW Convention, it is likely that the linkage issue would be far less contentious.

Change #1 - While it previously would not have been politically feasible, now with France and China indicating their intentions to become parties to the NPT, and Argentina and Brazil indicating their intentions to bring the Treaty of Tlatelolco fully into effect, perhaps a condition for becoming a Party to the RW Convention could be membership in the NPT or Treaty of Tlatelolco, or some other de jure undertaking for non-nuclear-weapon states not to acquire nuclear weapons and to place all nuclear material and facilities under safeguards. For parties to the RW Convention, material and facilities already subject to nuclear safeguards would be considered "safeguarded" for RW purposes as well. Admittedly, this approach would exclude defense facilities and nuclear material in defense programs in nuclear-weapon states. However, since all five of the designated nuclear-weapon states have made all or a significant portion of their peaceful nuclear facilities eligible for safeguards, such an arrangement would "capture" for RW verification purposes, at least theoretically, a large percentage of the total material and facilities in the world not devoted to defense programs. Setting aside defense facilities in nuclear-weapons states would not be popular in some circles, but it would provide a pragmatic solution. The notion of having "RW safeguards" inspections in defense program facilities that are not subject to nuclear safeguards is simply a non-starter.

This requirement for NPT membership or some equivalent nonproliferation commitment would bring a howl from those excluded from the regime. India and Pakistan probably would be two of the prominent howlers, and Israel might make a bleat or two in private. However, such a requirement would permit the RW Convention to make use of IAEA nuclear safeguards in some innovative ways. Since a separate RW inspectorate organization cannot be justified in terms of its cost in relation to its security benefit, it is logical to look to an established international organization with related nuclear inspection activities to which the RW verification function might be attached in an appropriate manner. The IAEA and NPT type nuclear safeguards are the most logical candidates.

One approach might be to require reporting the separation of certain highly radioactive isotopes, identified to be suited for potential RW purposes, when specified quantities have been exceeded. Declaration of intended use would also be required. This material could be subject to regular safeguards or special inspection while held in storage prior to being placed in some legitimate peaceful use, such as source material for a food irradiation facility. There could even be an obligation to store such material in a facility already subject to IAEA safeguards. If there were questions about the declared peaceful use that could not be resolved by providing additional information, there could be provisions for a special inspection beyond normal nuclear safeguards to confirm the declared use.

Additionally, when nuclear safeguards continue to follow high-level nuclear waste from reprocessing because of its residual plutonium content, the safeguards inspectors could collect certain information relevant to RW as well when the inspection involves a party to the RW Convention.

Should any problems or serious questions with regard to RW Convention compliance arise, they could be brought to the attention of the IAEA Board of Governors which might call for a special inspection of specified facilities and materials. Procedures to be used in such special inspections would have to be worked out in advance by the IAEA.

Change #2 - The principal objective of an RW Convention should continue to be to make RW use illegitimate and to seek to establish an international norm to prevent it. Allegations of use might be brought to the IAEA Board of Governors. The Board would be given the authority to call for a special RW use inspection if the allegations justify such action. This would require the IAEA inspectorate to develop a set of procedures to investigate cases of possible RW use by taking samples and measurements, and collecting other types of evidence. Should a party refuse to permit an IAEA Board mandated inspection to be carried out to investigate possible use, or should use be confirmed, the issue could be taken to the UN Security Council for consideration and possible sanctions.

Change #3 - If the RW Convention remains comprehensive, and there are good reasons for it to remain so, it might be possible to separate RW material into various categories subject to different reporting and verification requirements. With respect to material, any radioactive material has the potential to be used in an RW mode. However, only a significant amount of material having a high level of radioactivity has the capacity to inflict damage of any military significance. It is acknowledged that a mixture of raw high-level radioactive waste could be disbursed over an area to damage it or deny access. This also would constitute radiological warfare. However, the military value of such use would be uneven and unpredictable since the isotopic content of the material would be random. It also would make no sense spending verification resources in attempting to measure the potential for this type of crude use. There would be few, if any, characteristic signatures to detect until the waste material was used in a hostile act. A distinction should be made, even in war time, between an unintended, localized nuclear spill or release and use of RW to contaminate a target or target area. At the same time, it would not be desirable to establish a threshold below which parties might use RW to harass an enemy with impunity.

In addition to paying close attention to highly radioactive isotopes after they are separated, the RW verification regime should also require that facilities capable of separating or processing isotopes in significant quantities be declared. Laboratory scale hot cells or pilot plants with limited capacities would not be included. However, chemical reprocessing plants and other facilities designed to process highly radioactive isotopes would be declared. Most, if not all, of these facilities would already be covered by nuclear safeguards when engaged in reprocessing spent fuel.

In effect, the focus of the material accounting and inspection effort would be the most militarily significant threat, that is highly radioactive isotopes which have been chemically separated, but not yet packaged in a form designed for peaceful use. Any such radioactive isotopes, above a certain quantity, would be declared and the intended uses indicated. They would be subject to IAEA inspection, normally during the course of safeguards inspections of other nuclear material located near by. Some special equipment, in addition to standard nuclear safeguards equipment, would probably be required. While making use of nuclear safeguards, with a few RW enhancements, to monitor those nuclear capabilities that are the most significant in terms of RW potential, the main focus of verification would be on-site inspections to investigate allegations of use. Development, in advance, of procedures and special equipment to carry out such inspections promptly would be required.

Change #4 - If the RW Convention were to be closely associated with the IAEA and the NPT, the conditions for entry into force should be such that a substantial majority of the members of the IAEA Board of Governors are from countries that are parties to the Convention. One requirement might be that all five countries that are permanent members of the UN Security Council, and all countries that are members of the IAEA Board of Governors as a result of being designated as most advanced in the technology of atomic energy, and that are eligible to sign the RW Convention, must ratify the RW Convention before it enters into force. Another requirement might be, in addition, that a significant number of countries, perhaps as many as 40 - 50, must deposit their instruments of ratification before the Convention enters into force.

Alternative to Global Regime - Should international politics not permit the restructuring in the CD of the RW Convention as outlined above, it would make a certain amount of sense to convert the Convention into a CSCE undertaking, open to others who wish to participate such as Japan, South Korea, Australia, and New Zealand, and China. The Convention could have the same relationship with the IAEA as other "regional" agreements such as the Treaties of Tlatelolco and Raratonga (South Pacific Nuclear Free Zone) and could be open to full participation by others outside the CSCE group via an appropriate protocol.

Moving the RW Convention to the CSCE venue and concluding it promptly might well contribute to the North-South splits, and could be the death knell for the CD. During the run up to the NPT Extension Conference in 1995, we are likely to be trying to build North-South bridges and common interests in the area of arms control rather than creating additional sources of tension.

Conclusion

If there is a policy interest in concluding a RW Convention with adequate verification to deal with the most militarily significant potential threat, and yet avoiding the expense of creating a new international inspectorate that cannot be justified in terms of its contribution to international security, the approach to the Convention's restructuring and verification as discussed above might be considered. In sum, the possible RW initiative would have the following characteristics.

--radiological weapons would be clearly defined to exclude nuclear explosives and the radioactive products of nuclear explosions.

--facilities and materials in the defense programs of the five nuclear-weapon states would be excluded from inspection as long as such facilities and materials remain outside of NPT safeguards.

--materials and facilities subject to nuclear safeguards would be subject to RW inspection, normally during the course of such safeguards inspections, with special attention given to isotope processing and separation facilities.

--special attention would be paid to specified radioactive isotopes that have been separated and have the most significant military potential for RW applications (while not necessarily the sole criteria, radioactive isotopes that are especially dangerous to humans include iodine 131 with 8.5 days half-life and which concentrates in the thyroid, and cesium 137, a bone marrow and organ concentrator with a 30 years half-life and which represents a particularly insidious long-term danger when introduced into the food chain via contaminated soil.)

--should RW concerns arise with regard to any facility subject to safeguards, IAEA Board of Governors could call for special inspections. Any undeclared activities involving RW materials that also involved nuclear materials subject to safeguards would be a violation of the NPT (or a similar commitment.)

--suspicions of use can be taken to the IAEA Board of Governors with all parties obligated to permit inspection of the site of alleged use.

--if on-site inspection of use not permitted, or if use confirmed, issue may be referred to the UN Security Council.

--conditions for entry into force of the Convention ensure that all permanent members of the Security Council are parties and that a sufficient number of members of the IAEA Board of Governors are parties for the Convention to be protected from mischievous non-parties.

While there would be no direct verification attention given to verification of possible "development" of radiological weapons, or testing (which might be considered to be included under development), concerns could be presented to the IAEA Board of Governors and facilities of concern indicated.

In terms of verification equipment, the following list helps to illustrate the types of items that might be required, particularly in terms of on-site inspections of possible use.

--protective clothing

--sampling kits

--tamper indicating shipping containers for radioactive samples

--radiation detectors and alarms

--portable geiger counters and gamma ray spectrometers

--decontamination equipment

--portable mass spectrometers

--calibration samples

Procedures, with emphasis on protecting inspectors' safety, would be required for on-site inspections, given the inherent danger of a site that must be assumed to be contaminated.

If given the appropriate mandate and a very modest increase in resources, the IAEA could assume the responsibilities outlined above with a minimum of disruption to its regular safeguards function. Indeed, a case could be made that the challenge of planning and preparing for RW verification activities would actually enhance the IAEA's safeguards and special inspection abilities, as well as the Agency's capability to respond to nuclear accidents and emergencies.

Has the time come to consider an approach along these lines?

Changing Roles for Arms Control in a Changing Europe

T. Pounds
Science Applications International Corporation

Prepared for:
Conference on Arms Control and Verification Technology
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I. Overview

The end of the East-West rivalry in Europe has changed the security environment as well as the basis for multinational negotiations. The threat of large-scale military aggression from the East is no longer credible. However, policy makers now face a more complex and long-term set of inter-related challenges that entail the rebuilding of struggling economies, the mitigation of ethnic and nationalist rivalries, and, in the worst cases, the prevention and resolution of regional conflict within and between states of the former Soviet Union and Eastern and Central Europe.

In response, governments with a stake in Europe have been reviewing their individual and common security priorities and policies. The main emphasis of this process has been to create new, and expand the scope of existing, political, economic, and military institutions as a basis to facilitate a more stable transition to a post-Cold War European security environment. A concerted effort has been made to integrate former members of Warsaw Pact and Soviet Republics into European security institutions such as the North Atlantic Cooperation Council and the CSCE as part of a new emphasis on cooperative security arrangements. As well, a number of institutions such as the CSCE, EC, and UN have attempted to mediate in ongoing disputes in Yugoslavia and Nagorno Karabakh, although without much success.

At least in principle, arms control as broadly conceived is viewed by many North American and European officials and observers as an important instrument in this transition. But beyond the horizon of the next 12 months, it remains unclear whether it will be feasible to adapt traditional arms control approaches to new political-military realities. Assuming that arms control is not an end in itself, what types of political-military problems might arms control help to address, and how? What roles do countries participating in the CSCE process envisage for arms control? How realistic are these expectations? To what constraints might future arms control efforts in Europe be subject? And what are the implications for thinking about future verification requirements and approaches?

In addressing these questions, Section II of this paper will examine European security problems and how arms control might fit in. Section III examines ongoing efforts in the CSCE Helsinki Follow-Up Conference to identify what types of potential roles and what concrete arms control proposals have been suggested for the post-Helsinki negotiation process. Section IV assesses potential constraints likely to affect this process and examines possible implications for verification policy.

II. Defining Arms Control in the Post-Cold War Era

Since the early 1970s, arms control has gone through two distinct stages. In the SALT I and II negotiations, as well as in the ABM and MBFR talks, the focus on arms control was establishing ceilings in agreed areas to prevent the expansion of an arms race. Beginning in the ear y 1980s, the focus on arms control shifted to negotiating actual reductions. This approach led to the eventual elimination of an entire class of weapons under the INF Treaty, significant reductions of strategic nuclear missiles and warheads under START, agreement n destruction of chemical weapons stocks between the United States and Soviet Union, and large-scale cuts in conventional weapons under the CFE Treaty. In addition, confidence-, security-, and transparency-building measures became a prominent part of the arms control agenda during this period.

Arms control in the 1970s and 1980s also shared some common characteristics. Most arms control proposals and agreements related to Europe focused primarily on establishing quantitative parity between two military blocs. In the 1980s, the objectives of conventional arms control talks were refined to aim at achieving regional balances of regional military power and mobilization capability through the CFE zonal approach. In almost all cases, arms control sought to enhance stability and establish incentives against military aggression through the maintenance of numerical parity and enhanced transparency.

Now that one military bloc has disappeared, the relationship among states at the sub-regional level has become the main focus of security building in Europe. Arms control as traditionally conceived has lost much of its relevance to this situation due to the breadth and speed of political change in Europe and the inability of negotiations to keep pace and the fact that military regional balances cannot be addressed simply through quantitative formulations of military parity. Indeed, the idea of quantitative parity in the current environment is itself ponderous.

As a result, the concept of arms control is being absorbed into the broader idea of building more cooperative security relations among European countries. "Cooperative" in this sense is defined by the conduct of militaries in accordance with established norms and expectations concerning the use of force. Measures to enhance this cooperative spirit might eventually entail further negotiated cuts, but in a European environment where such cuts are being driven in most countries by budget pressures, the main emphasis of security building is shifting towards enhanced military contacts, cooperation in defense planning, defense conversion, and even defense-related environmental issues, to name but a few areas.

This is not to say that military threat or the containment of military power through negotiated means have become obsolete concepts; on the contrary, both remain relevant for many

Europeans. However, military power is increasingly perceived as being one of several factors in the broad range of security concerns facing Europe. In order to evaluate arms control's prospects in a just manner, an assessment of arms control's relation to existing security problems is needed.

III. Emerging Security Problems

The large-scale conventional surprise attack that was for almost four decades the focus of Western military strategy is gone. This development has increased a sense of strategic military breathing space, but at the same time, the rise of nationalism and ethnic animosities as well as the presence of military conflict in the east and south are viewed as sources for serious concern. All require a coordinated, multi-dimensional approach, and some are time-urgent, although not all evolving problems are perceived with the same priority. For the countries of Eastern and Central Europe, many of these same problems are seen as matters of survival.

The relevance of arms control varies in its ability to constructively address these problems. In some cases, the entry into force of existing arms control agreements will be more important than new arms control talks. However, in some areas, new arms control discussions could play an important part in establishing a more cooperative security environment in Europe.

More specifically, four general problems confront policy makers dealing with the current and future security of Europe. In brief, these are:

Soviet Dissolution. The disintegration of the Soviet Union has removed any threat of a consolidated Soviet attack against the West. But unstable relations among the republics as well as the harsh social, economic, and political conditions within them increase the prospect of local or wide-spread instability (including military conflict). This situation carries implicit if not explicit risks for the new countries themselves, neighboring countries, and existing international structures. It also has meaning for future strategic relations between the United States and the two biggest sovereign republics, Russia and Ukraine.

In broad terms, Russia and the other republics seek large-scale international investment and aid programs designed to lock-in the changes that have been achieved and to encourage further developments. Not least, these new countries also seek acceptance in Europe in the form of increased association and eventual membership in Western institutions such as the EC and maybe even NATO.

In the near-term, one priority will be to preserve the Non-Proliferation Treaty regime. At present, a pressing danger to this regime is the possibility of dealing with four nuclear successor powers where there once was one. This problem seems to be viewed with a common sense of urgency by Eastern and Central European as well as by Western countries. The recent quadripartite agreement among Ukraine, Belorussia, Russia, and Kazakhstan to transfer all nuclear weapons to Russia in the context of the START Treaty is one suggests that an important element of this problem is being addressed diplomatically. Reports that all tactical nuclear weapons have been transported back to Russia, also have provided some reassurance that the problem is being managed.

However, ratification and entry into force of the START Treaty and the signature of Ukraine, Belorussia, and Kazakhstan of the NPT Treaty as non-nuclear powers is by no means guaranteed. Although all three countries have pledged their desire to become non-nuclear weapon states, they have made no commitment concerning when they intend to sign the NPT Treaty. Moreover, the terms of quadripartite agreement now give Ukraine seven years to remove strategic nuclear weapons on its soil, whereas they had previously committed to remove them within four years. As a result, continued Western pressure and persistence will be important to ensure that the terms of the quadripartite agreement are fulfilled, the START Treaty enters into force, and the Non- Proliferation Treaty regime is preserved. And Western cooperation will be needed if the timely and safe control, storage, and dismantlement is to be achieved in an effective manner.

A related challenge concerns strategic relations between the United States and Russia in the area of ballistic missile defenses. The modification of the ABM Treaty will probably be discussed during the Bush-Yeltsin Summit in mid-June, and formal negotiations could begin in Vienna later this summer. The Bush Administration has received authorization in the 1991 Missile Defense Act to seek an expansion in the number of ABM sites allowed and agreement on conducting tests on space- based ABM components and interceptors, as well as their deployment, although this last element remains very much the source of congressional dispute.

The Russians, for their part, have kept their position ambiguous. On one hand, Russian President Boris Yeltsin declared twice in February 1992 that he supported a cooperative US-Russian development project in the missile defense area. His advisors have expressed particular interest in sharing technology capable of enhancing early warning of missile launches. By contrast, Yeltsin and his advisors are also on record as supporting the maintenance of the ABM Treaty. The Russians have not objected publicly to the Bush administration's desire to modify the ABM Treaty; nor have they expressed much enthusiasm for it. To date, the Russians have no public position on what would be acceptable modifications to the ABM Treaty. Their willingness to accept significant revisions probably will reflect the degree to which the Bush administration is ready to engage in cooperative development of future ABM technology and even financial assistance. The United States and Russia have already agreed to cooperation on sharing information to enhance early warning of ballistic missile launches, but how much further the Bush administration will go is unclear.

Another near-term challenge is the resolution of debate among the former Soviet republics over possession of the former Soviet military. This resolution is a necessary condition for the entry into force of the Conventional Armed Forces in Europe (CFE) Treaty. While the CFE Treaty has lost much of its significance in terms of stabilizing East-West military tensions, its entry into force remains an important security priority, not least for countries bordering the former Soviet Union, but for the other 21 signatories that have already ratified the agreement.

Moreover, the resolution of debate over the future of the former Soviet military is important for establishing better relations among the new sovereign republics. Russia's tensions with Ukraine, for example, over possession of the Baltic Fleet is a bad precedent for establishing peaceful relations. Agreement among the eight sovereign republics at the Tashkent Summit in May 1992 on how to divide up the former Soviet army (with Russia agreeing to accept as its share roughly 50 percent of total combat equipment) is an encouraging sign. Subsequently, agreement at the Oslo Ministerial in June 1992 among CFE signatories to add the Tashkent agreement as a protocol to the CFE Treaty has paved the way for eventual implementation. However, all eight countries (plus Turkey) must ratify the agreement and the CFE Treaty, and such a process will likely require patience and persistent diplomacy on the part of Western countries.

As well, better relations among the sovereign republics and with their outside neighbors might be helped by an ongoing dialogue on security issues and perhaps by agreement on measures to enhance transparency and predictability in military relations. Even if the CFE and Vienna 1992 Documents are implemented, suspicions concerning political intentions and military behavior, not to mention fears about potential accidents, are likely to continue. Northern Europeans cannot help but be uncomfortable in the face of large numbers of former Soviet naval and ground forces. Eventually, a dialogue might lead to future reductions in areas where political uneasiness is most acute. Future agreements on military operations might also contribute to better relations and lessen the chances of conflict among the new republics and countries in Eastern and Central Europe.

<u>Survival of Reform and Security Concerns in Eastern Europe</u>. The emergence of democratic reform and pursuit of market economy structures in East and Central Europe has also created security needs in the near and long-term. These countries have an interest

in ensuring that their reform processes do not fail, however much hardship they generate in the next few years. Based on public statements, the West shares this interest as well, but the extent to which this process is viewed as a common problem is still unclear. For neighboring West European countries, such as Germany, the successful transition is an urgent requirement, not least because of potential refugee waves in the case of economic collapse or political chaos.

More broadly, the central Eastern European countries (Hungary, Poland, and Czechoslovakia) have begun to express their security concerns and perceptions. They have established cooperative security agreements with each other and they have made known their need of closer association and eventual membership in prominent Western institutions (NATO and the EC); this desire has an economic as well as a traditional security dimension. At the same time, they have also expressed uneasiness about future political and military relations with their immediate neighbors, particularly Russia.

In this context, a dialogue on security issues as well as further agreements on military operations and eventually on further force reductions might feasibly enhance the security of these countries. Several East European countries have also expressed support for further reductions in military personnel and combat equipment of some of their larger neighbors (e.g., Russia, Ukraine, Germany) as a means to address some of their security concerns. Particular emphasis on measures to enhance transparency of defense planning processes and institutions might also help to lessen anxieties and provide reassurance to countries in East and Central Europe.

Local Ethnic and National Conflict. Conflict exemplified by fighting in Yugoslavia and Nagorno Karabakh is probably the most topical security issue in Europe. While these conflicts have remained essentially local and not posed an immediate threat to the territory of other European countries, they pose potential border incursions against neighboring lands, refugee waves, and longer term economic problems. Moreover, they threaten the credibility of institutions that have yet to find an effective response to these conflicts.

In addressing existing civil war conflicts, the utility of arms control is likely to be extremely limited. The political will among warring factions is a precondition to any type of negotiations, and without such will, any arms control talks would likely degenerate. However, interim arms control measures might help in the initial disengagement of conflicting forces. In the longer term, transparency measures, creation of military stationing zones, and other local measures might help to facilitate better political relations. Agreements among bordering countries concerning the handling of refugees and the movement of military troops and equipment might also provide some means of preventing ongoing conflicts from spreading.

Concerning potential conflict between European states, existing arms control agreements and future agreed measures in the context of a broader security-building framework could have more utility.

Non-Proliferation. Perhaps the most pressing nuclear non-proliferation challenge stems from the break-up of the Soviet Union. Sorting out custody of strategic and tactical nuclear weapons will influence significantly the prospects for the survival of the NPT regime. The next priority area is the several threshold nuclear weapons powers, such as India, Pakistan, and Israel. European countries in East and West will need to agree on a strategy to discourage these countries from becoming overt nuclear powers, promoting confidence building measures where possible, and emphasizing a regional approach to reduce political instabilities. Where developing nuclear powers are concerned, the NPT and London Supplier countries should continue to revise export controls and safeguard arrangements to increase the political and economic disincentives for nuclear weapons technology acquisition.

IV. Arms Control and the Post Helsinki Security Forum

Future European arms control initiatives are only one element of the Helsinki Follow-Up Conference that is currently underway. Beyond arms control, the security forum mandate will address:

- how to ensure that the new member states from the former Soviet Union will fulfill CSCE obligations and resolve peacefully the question of how to structure and organize the former Soviet military forces in order to satisfy individual and collective security requirements; and

- how to develop and strengthen the CSCE's role in conflict prevention and management.

The successful incorporation of the new members into the CSCE process is a recent goal that has arisen as a result of the altered geo-political situation in the former Soviet Union. Chronic instability in this region and in Eastern Europe has, in turn, made the issue of conflict prevention and management an even more urgent priority. The new mandate for future arms control will be an instrumental tool for promoting both conflict prevention and a smooth transition to military stability in the emerging democracies.

Another issue on the Helsinki agenda, moreover, will focus on the broader question of the CSCE's future role as a European security institution. This will include consideration of the type of mandate, authority, structure, and process that will be needed to enable the CSCE to act effectively in security affairs. Members will also examine the CSCE's relationship to existing European security arrangements such as NATO and the Western European Union (WEU). The definition and shaping of a new security role will influence how the CSCE approaches all of the specific concerns listed above.

The ability of CSCE countries to make progress on this issue will depend to some extent on their ability to find a common denominator in their security interests. There are diverse conceptions among different members of what this role should be, however, which could delay the development of the new institution as well as undermine the CSCE's ability to address current priorities and to cope with urgent problems.

Post CSCE Security Forum: Background. The completion of the Vienna CSBM document of 1992 brought the negotiations on confidence and security building measures to an end in accordance with the CSCE 1983 Madrid and 1986 Madrid mandates. That did not end, however, the CSBM concept or the possibility of future negotiated arms control measures under the auspices of the CSCE. The Charter of Paris instructs participating states to "seek to conclude" both the CFE IA negotiations and the all-CSCE CSBM negotiations no later than Helsinki. While the latter task has been achieved, the former has not. The Paris Charter also states that from the conclusion of the new Helsinki meeting, "new negotiations on disarmament and confidence and security building open to all participating states" are to be established.

At the June 1991 Berlin CSCE Foreign Ministerial meeting, CSCE members decided to begin informal preparatory consultations within the Consultative Committee regarding new conventional arms control negotiations, termed "Security Forum" by some delegations to reflect that security in Europe could not be confined to disarmament alone. The Prague Ministerial in February 1992 also referred to Helsinki crisis management from peaceful settlement of disputes to peacekeeping, further elaboration of the "consensus-minus-one" principle, cooperation with other international organizations, and support to new member states.

The problems related to recent arms control agreements have in some ways slowed work on developing a future arms control agenda. Officials in Prague set a tentative timetable for the new CSCE members to ratify existing arms control agreements. The parliaments of the new seven states, as well as the Russian parliament, now have roughly until the end of July to conclude ratification proceedings. The agreements might then be ready to enter into force by the end of the Helsinki summit in late June or early July.

Another issue has been how to apply already agreed measures to new CSCE members. There appears to be widespread agreement that human rights-related provisions should apply to all of the territory of the new members, but there is less than a full consensus on whether this approach should apply to arms control as well. A majority of CSCE countries appear to favor a solution that would apply the Vienna 1990 document and other relevant agreements to the territory of all the new members, including the seven independent Asian republics. Under this approach, the likely solution would be an additional annex to the Vienna 1992 document and any additional CSBMs that would, in effect, expand the area of application to include the territory of these countries. However, a few countries such as Turkey seem to favor reopening the agreements for negotiation where the area of application is concerned.

Questions also remain concerning the obligations of new CSCE members to arms control agreements that are still under negotiation (CFE I-A). Most countries seem to favor an approach in which relevant successor countries would become a signatory to these politically-binding agreements as a condition of their entry. Negotiations on expanding these agreements to other CSCE members would then be undertaken after the Helsinki Conference is completed. However, details concerning exactly how these agreements might be modified to accommodate new signatories remain to be finalized.

Given past uncertainty about whether the CFE Treaty and the Vienna document signed at Paris will even enter into force, many countries have been reluctant to talk in concrete terms about the future. As a result, the mandate talks are not that far along. Informal discussions in Vienna are still focusing on conceptual issues such as structure and substance and have not addressed specific details. These are discussed in greater detail below.

Future Security Forum Structures. Two main approaches and some variants have emerged in the discussion about the structure and organization for addressing future security issues. One approach, which is favored by Germany and France, entails three main elements. One element would be the Conflict Prevention Center (CPC). The CPC would have specific functions assigned to it including treaty implementation support, ad hoc dialogues, and possibly, arbitration. It would also provide political guidance to the other fora. The second element would be an ongoing, CSCE-wide security dialogue that would focus on identifying and discussing security issues that might then lead to negotiations in the third pillar, the actual negotiations.

A U.S. variant to this approach favors two separate negotiating fora that would divide future arms control discussions between a Europe-only compartment and a broader, CSCE-wide compartment. This would allow the United States to avoid the expansion of the traditional ATTU mandate area, but at the same time, it would allow the United States to participate in European arms control negotiations.

A second approach, which has been supported by Great Britain, Italy, and the Netherlands, among others, involves a two-element structure. Under this scheme, the mandate would be organized into two categories. First, the CPC would conduct the security dialogue as well as other functions. The second element would be a forum for the actual negotiations. Proponents of this approach seek to avoid organizational redundancy. They also tend to be countries with smaller, lower-budget delegations in Vienna that cannot afford to monitor multiple proceedings at once.

Future Arms Control Substance. Aside from structure is the issue of substance. The discussion thus far has focused on identifying a priority list of potential subjects for negotiation. There is no consensus yet, but there is support for negotiations that would address additional measures to enhance the Vienna 92 document. While few details have been specified, the negotiation of new stabilizing and confidence measures related to conventional forces, including measures to address force generation capabilities, might increase transparency and cooperation in the area of defense planning, budgeting, force modernization, and military operations in the same area of application (plus some or most of the territory of former Soviet republics not already included -- to 90 degrees East of Greenwich). Beyond this, there are many suggested areas for priority action. These include:

- Harmonization. This area would apply to CSCE members who are not CFE, CSBM, or Open Skies signatories. It would seek an "appropriate harmonization" of the obligations of participating states to all CSCE arms control measures, beginning with the CFE and CFE I-A Treaties. Some countries view as a priority the absorption of CIS republics and neutral countries into the CFE regime. A German paper from NATO HLTF in September 1991 states that: "It will be important to expand the CFE Treaty as a common basis for negotiations among all CSCE participating states even in the initial phase of the new negotiation," such that the neutral and nonaligned countries "should therefore be invited to commit themselves to the essential parts of the CFE regime in politically binding declarations," including willingness to adopt national equipment limits and to adopt the respective regulations for information exchange, notification, and verification. However, it is unclear how to apply force limits assigned to specific groups of states to a broader community of countries. Moreover, some states oppose CSBMs because they would conflict with their national force postures (e.g., Switzerland's national mobilization force).

- Non-proliferation. Beyond a Prague agreement to expand the UN's conventional arms control register regime to all CSCE members, there has been discussion on enhancing coordination among members to strengthen non-proliferation in the conventional and nuclear fields. As envisioned by some members, the CSCE would be used as a supplement to existing non-proliferation regimes to shore up weak points, coordinate national efforts, and provide the establishment of a responsible approach to international arms transfers. But no specific proposals have been made public.

- Future conventional force cuts. There has been some discussion on, but not widespread support for, pursuing cuts in ground and other equipment with the goal of establishing national limits in a CFE follow-on agreement. There has also been discussion of naval arms control, which is especially favored by countries facing the remnants of the old Soviet navy like the Netherlands, Denmark, and Iceland. The United States is likely to continue to block efforts in this area.

- Global exchange of military information. The negotiation of further transparency by means of a global annual exchange on equipment and personnel has been proposed. Such a regime might include information on the production of military equipment.

Area of Application. Another key issue is the future area of application. This has been the subject of debate in the CSCE and Atlantic alliance, and a number of contending interests are involved.

The United States maintains that, because it is a global power with global interests, U.S. territory and forces outside of Europe should not be subject to numerical limitations or constraints on activities. To ensure that this condition is met, the U.S. delegation has argued that there must be clarity about the area of application for each arms control negotiation. Thus, as stated before, the United States supports the creation of a Europe-only negotiation forum. By contrast, Britain would prefer to negotiate in a common forum and simply specify the area of application for each measure.

The Unites States, together with most other CSCE members, has supported the expansion of the area of application to include former Soviet territory outside the ATTU (i.e., east of the Urals). Russia has expressed its willingness to consider such an expansion, but it has insisted on reciprocity from countries in North America.

Turkey continues to demand the continued exclusion of territory in Southeastern Anatolia from future arms control measures, much to the dissatisfaction of Greece. If these territories are excluded, other countries in Asia that share borders with Afghanistan, Iran, or China would also have a precedent to demand the exclusion of some of their territories from the area of application.

Western European countries, for their part, have expressed a desire to widen the area of application. F nce, in particular, has argued strongly that all future measures should be applied to the territory of all members. Germany and other West Europeans appear to be more pragmatic in their outlook, seeking to widen the area of application where practical without allowing the issue to block future talks.

Although no formal consensus has emerged, there appears to be widespread support for including Russian territory east of the Urals, not least from Ukraine and other CIS members. CSCE members refer frequently to formula that would extend the traditional European Area of Application eastward to 90 degrees East of Greenwich. Whether Russia will accept this formulation without some compromise by the United States concerning the application of measures to territory in North America is unclear. The issue is likely to be addressed at the mid-June Summit meeting between President Bush and President Yeltsin. Concerning exceptions of territory of CSCE members in Asia, there are fewer signs of any emerging compromises. Based on the exemptions of Southeast Anatolia from the CFE Treaty and CSBM agreements, Turkey has a strong precedent for demanding continued exemptions. However, this issue caused major difficulties throughout the CFE negotiations, and it probably will not be resolved easily in the post-Helsinki mandate talks.

Regional and Selective Measures. Another related issue is how the CSCE will fulfill its new mandate in the area of ad hoc discussions among member states. In particular, France and Germany have proposed the creation of re;ional groups with some power to discuss regional problems and make recommendations. This might involve building on measures of regional arms control such as the bilateral agreements between Bulgaria and Greece and Bulgaria and Turkey concluded in December 1991 and January 1992 regarding restrictions on military activity near common borders. Such an approach might involve more stringent and meaningful restrictions that would otherwise be unacceptable to all participating states. The main rational is that such groups could address security problems expediently by not involving every member, thereby facilitating time-urgent action. Key questions include how such groups would be formed, what type of procedures would be used to set agendas, how these groups would related to larger CSCE organs, and what type of voting system would be used.

The complicated nature of all these issues to be addressed at Helsinki and the lack of specific progress made in preparatory

meetings suggest that it is unlikely that a detailed mandate will be completed at Helsinki or any time soon. The debate thus far has focused on structure and substance, while ignoring the more fundamental question of the specific goals of arms control.
New states that join the CSCE must also assume any arms control obligations undertaken by their predecessor governments. This includes the CFE Treaty and CFE I-A accord (where applicable), Stockholm 1986 and Vienna 1990 CSBMs, and any other relevant agreements.

V. OBSERVATIONS, IMPLICATIONS, AND CONCLUSIONS

The role of arms control as a center piece of U.S.-Soviet and broader East-West relations seems to be passing, and the success of future European arms control initiatives is uncertain. Clearly, arms control will not enjoy the prominence it once did. In fact, in promoting the idea of a cooperative security fora in the post-Helsinki 1992 CSCE framework, there has been a conscious effort not to limit security negotiations to arms control and disarmament negotiations.

In part, this situation reflects the rapid pace and wide breadth of changes in an international context which saw arms control used as prominent instrument of foreign policy. The absence of an immediate, large-scale military threat means that some countries no longer perceive the need to engage in traditional (i.e., formal and usually quantitative) forms of arms negotiation.

Perhaps the most pressing arms control problem has been the fate of already agreed arms control arrangements is under scrutiny. Due to instabilities in the former Soviet and now fully sovereign Republics, there remained serious doubt only until recently whether the CFE and START as well as other agreements would even enter into force. The entry into force and implementation of these treaties now appear more likely, but by no means are they guaranteed. But assuming they do enter into force, the utility of future arms control initiatives in the near-term appears unclear.

Some national leaders, for instance, now prefer to handle serious security and arms control issues through bilateral channels. Moreover, unilateral arms reductions are occurring throughout Europe because of decreasing defense budgets. Countries that have restructured and reduced their forces in response to new military realities might not have any incentive to engage in negotiations about future cuts that would diminish their ability to restructure forces according to their own needs. Further, the CSCE with its 52-plus participants, does not offer a sufficiently flexible format for far-reaching arms reduction talks. Not least, the conceptual basis for conducting multinational negotiations in a new environment remains to be defined and elaborated, especially in the area of how such negotiations will be managed and ultimately implemented. It is in this area that the Helsinki Follow-Up Conference has the farthest to go in identifying future concrete areas for arms control and security-related talks.

In assessing arms control's changing role in a changing Europe, it is important to recognize the new security challenges that have replaced the political-military rivalry of the Cold War. The problems outlined and discussed in Section III of this paper reflect a security order that is characterized less by the potential for a world-wide intensive conflict and more by the nagging potential of local conflicts that might eventually expand to regional ones. Instead of containing the political and military influence of another superpower, the main security challenge in Europe will be to prevent the crumbling of, and conflict among regional powers.

To the extent possible, arms control as an instrument of foreign policy needs to be modified to better suit this new goal. Arms control needs to be thought of in a broader context that extends to security building. This adaptation process will have implications for future substance of future European arms control endeavors. In the near-term, it will be important to create a mandate that fosters a continuing dialogue on European security issues. The arms control component of this dialogue will likely be limited because of the fast pace and wide breadth of political change. However, the mandate should be kept flexible enough to allow the arms control agenda to expand in the future.

Concerning substance, some additional CSBMs may be at least marginally important and even helpful in fostering a more cooperative security environment in the near-term. Measures aimed at enhancing transparency in military planning, mobilization, and operations should continue to be discussed. Beyond this traditional area, military-to-military contacts and collective undertakings as humanitarian relief, peacekeeping, environmental clean-up, defense industrial conversion, and arms export control probably will take on increasing importance. The potential for East-West and pan-European political and military cooperation in out-of-area contingencies should not be dismissed, and these might provide the CSCE, NACC, and other organs important new roles. The idea of creating regional arms control tables, as objectionable as that may be to some countries, also could offer new avenues for security-building among countries with special regional military security concerns.

Regarding the role of verification in this new security-building context, a new emphasis must be found to underscore the importance of the desired cooperative character of the security environment. Emphasis on inspections and use of monitoring technology as a means to detect and deter cheating is unlikely to promote such a cooperative spirit. Verification as a means of enforcing arms control agreements carries a negative stigma of mistrust in the emerging European environment. Thus, in the context of a widening of the European security concept, the conceptual basis for verification should be widened.

Given the vast network of verification regimes in place from previous agreements, it is unlikely that verification policy will be the critical linchpin it once was. Emphasis on cooperative implementation of past and future security-related agreements might be way to adapt traditional verification approaches to the future. Speaking concretely, this type of approach might build on the contacts being established under a NATO work to provide Russian experts with the expertise of experts from the West in the area of safer nuclear weapon transport, storage, and dismantlement, as well as in area nuclear materials conversion. Another area for such cooperation might be in the area of chemical weapons.

In conclusion, one of the biggest challenges will be to define terms such as "collective security" and "Vladivostock to Vancouver" in a way that can lead to fruitful discussion. It appears that officials at Helsinki are not going to find all the right answers. Indeed, it remains unclear whether they will agree on the right questions. The success of security building efforts will depend on the ability of arms control and security-related officials to set a course that will make arms control as an instrument of security building more rather than less relevant in the European security arena.

Strategies for Biological Weapons Verification

S. Morse
The Rockefeller University

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STRATEGIES FOR BIOLOGICAL WEAPONS VERIFICATION

Stephen S. Morse
The Rockefeller University
New York, NY 10021-6399

SUMMARY
Chemical and biological weapons present special challenges for arms control and verification. While many of the problems with biological weapons verification are similar to those now being addressed with chemical weapons, biological weapons present some unique additional difficulties. For example, biotechnology has made the development of potential biological weapons agents cheap and relatively simple, requiring only limited equipment. The purpose of this paper is first, to discuss how verification might be carried out; second, to describe trial efforts to date and the lessons derived from them; and third, to suggest what kinds of additional systems might strengthen verification. To summarize briefly, the most effective option presently available is a system of declarations by States Parties, together with independent inspections to verify compliance with declarations. Trial visits indicate that such a system is technically feasible, and these trials have helped to suggest how an inspection regime might operate. The system would be further strengthened by provisions for *ad hoc* epidemiolgic field investigation of unusual outbreaks and by confidence building measures. In order to encourage states to become parties to a Biological Weapons Convention, such confidence building measures as personnel exchanges, a vaccine production program, and global infectious disease surveillance, should be included as ancillary measures. In particular, global infectious disease surveillance, undertaken primarily for public health purposes, would benefit human health worldwide while also simplifying identification and investigation of alleged use.

Chemical and biological weapons present special challenges for arms control and verification. Unlike nuclear weapons, which require large highly specialized facilities for production and handling of fissionable material, both chemical and biological weapons can readily be produced in plants disguised as conventional chemical or bioproducts plants. Even with technical surveillance, proving that a suspect facility is being used for weapons development is difficult and can be controversial.

While many of the problems with biological weapons [BW; in this paper, BW will be used to refer to both biological and toxin agents] verification are similar to those now being addressed with chemical weapons (CW), biological weapons present some unique additional difficulties. Table 1 lists a few of the major features of BW and BW agents relevant to verification. Chemical weapons usually require specific precursors or other raw materials that may be identifiable and can be subjected to export controls. Although CW plants can be difficult to identify or might be disguised as civilian chemical plants, specialized facilities are required, and the factories must generally be fairly large, further improving chances of detection. While some BW facilities, especially production facilities, can be large and can contain specialized equipment, this is not a necessity for much BW work, especially in research facilities. Worse, the inevitable advance of biotechnology, by offering many additional options for BW development and production, will make verification increasingly difficult. The relative simplicity of BW technology has led some to call biological weapons "the poor man's atom bomb" (Carus, 1991), despite the numerous practical disadvantages of biological agents as weapons in comparison with more conventional armaments.

Despite these differences between BW and CW, there are close parallels, both at the scientific and especially at the organizational level, between measures for BW control and those for CW. At the organizational level, it is expected that many of the procedures and protocols negotiated in the CW conventions will be mirrored by BW counterparts. Legal arrangements for access to proprietary industrial data, methods for protecting confidentiality, agreements for inspection visits, logistics of inspections, and possibly an organizational structure for monitoring compliance are all aspects of the CW Convention that are presently under discussion and that may be resolved at about the time these questions are expected to be considered by the BW Convention. As the specifics of CW verification are considered by other contributors to this volume, I will concentrate here on issues specific to BW compliance.

For both the BW and CW conventions, it is generally agreed that some mechanism is needed to assure that all signatories are in compliance with the agreed terms of the Convention. Thus, some form of compliance assessment or verification seems inevitable. The general characteristics of a suitable compliance or verification regime have been discussed (FAS, 1990; Haar, 1991). In one definition (FAS, 1992 report; see Appendix) "the objective of a good compliance regime is to provide transparency in the uses" of biological agents and allow "warning of any misuse". It should be fair to all parties, not overly intrusive, and offer positive incentives for compliance. Fairness implies that all must play by the same rules: the burden, whether financial or regulatory, is evenly borne by parties in proportion to their resources and activities. Mechanisms should exist to resolve disagreements, so that no party feels unjustly accused, as well as to encourage correction in cases of apparent non-compliance. As confidence building measures, there has also long been general agreement in principle on the value of exchanging information on national biological defense research and development programs, on disease outbreaks (United Nations, 1992, p. 14), and on methods for biotechnology, although action has been variable.

By analogy with the "chokepoint" concept in CW control, most groups working in BW verification have concentrated on various stages of development and production, considering this the major challenge. Less attention has been devoted to delivery systems, on the assumption that these will often be of a more obvious military character, hence less easily concealed. Similar to other types of industrial production, there are a number of steps in BW agent development and production (Table 2). By virtue of their scale, the later stages (5 and 6 in the table) are harder to conceal. In addition, scaling up to full production can meet with unanticipated technical difficulties. The stage immediately preceding loading into delivery systems, large-scale production for ultimate use, may be less obvious but also often would require some effort at concealment. While these generalizations are not always true for all biological agents, it is a useful simplification and provides a good starting point. In keeping with this view, the Third Review Conference of the BWC (United Nations, 1992) charged its Ad Hoc Group of Governmental Experts with the responsibility of seeking to identify potential verification "measures which could determine... whether a State party is developing, producing, stockpiling, acquiring or retaining micobial or other biological agents or toxins, of types and in quantities that have no justification for prophylactic, protective or peaceful purposes..." (p. 17).

One question raised (as in this quotation from United Nations, 1992) is what constitutes a BW agent subject to control. Definitions of BW agents vary somewhat, and, especially, exact quantities that would require control have long been debated. However, this question is potentially easily resolvable. For example, various lists of BW agents that have circulated (FAS, 1990; Geissler, 1992; United Nations, 1992) show reasonable agreement. Quantities that require a declaration by the possessor can be decided arbitrarily by agreement; I will return briefly later to whether this may be unduly burdensome.

Virtually all proposals for enforcing the BW Convention call for States to make various declarations, to be collected and tabulated by an international agency. Among other items, States would declare all facilities that are working with sufficient quantities of potential BW agents or have the capability to do so. Among the possible facilities are vaccine plants, which could be converted to BW production; in addition, vaccines against BW agents are usually required to protect the personnel and troops of the party using the agent. As a confidence building measure, the Third Review Conference proposed that all States Parties declare vaccine production facilities (United Nations, 1992, p. 15).

A major debate hinges on whether additional security would be gained by going further, by implementing a protocol that would involve actual physical inspection of facilities in addition to collecting declarations. The basic elements of such a proposed plan for compliance assessment are shown in Table 3 (based on a proposal by FAS, 1992, see Appendix; copies of the full report can be obtained from Federation of American Scientists, 307 Massachusetts Avenue, N.E., Washington, DC 20002). However, the difficulties of monitoring and detecting biological agents (Table 1) lead some to question whether an effective compliance assessment or verification program is practicable. In order to help answer this question, for the last several years an expert Working Group on Biological and Toxin Weapons Verification of the Federation of American Scientists has been considering methods for verification based on declaration of facilities and inspection visits. In the past year, this group has carried out several trial visits in order to determine the practicability of inspection procedures. Facilities visited were representative of the types that would be covered by an inspection protocol, and varied in size. These visits have led to proposals for draft verification protocols (the Appendix contains portions of a preliminary draft of this proposal).

One possible objection to compliance assessment is technical. The diversity of BW agents, and the future possibilities of making novel agents by biotechnology, suggest the inference that agents can always be made that will escape detection. How could one find such agents in an inspection? There are two answers to this question. First, some idea of what one is looking for is always helpful, and chance will always play a role, but one can improve the odds somewhat by developing and utilizing a number of sensitive broadly-based methods (especially those adaptable to screening for families of agents), such as PCR (polymerase chain reaction) for DNA sequences or ELISA for antigens and protein toxins (further information can be found in the Appendix on Identity Testing of Agents in the full FAS report, 1992). The biotechnology that can be used to make the novel agents can also be used to design suitable detection systems for these agents. Experts invited to address a seminar at the Quaker United Nations Office in Geneva (April 1992) shared similar views about the practicability of inspection.

Second, the odds are improved further by the fact that the inspection protocol operates in conjunction with the declarations. I believe this to be a crucial point, as either the declarations alone or inspection alone is far weaker than both together. One does not need to exhaustively test every possibility, but only to decide whether what is seen is consistent with the declarations. While the possibility that inconsistencies will be detected is still dependent on luck and skill (in either inspection or concealment), the level of effort and skill required for successful concealment is considerably increased.

These impressions are partly derived from experiences with trial visits. Summarizing briefly my conclusions from FAS trial visits in which I participated, although complete assurance is not possible, an inspection of reasonably short duration (e.g., 1 day to 1 week depending on the facility) and moderate cost can provide valuable evidence to suggest whether the facility is operating in a manner consistent with its declarations. During inspection of facilities, inspectors may detect various types of inconsistencies with declared information. Any inconsistency with declarations would suggest possible failure to comply. Some examples of specific items for consideration might include the following: (1) Assessment of biosecurity precautions (air flow patterns, containment enclosures, etc.) is easily and objectively done during routine inspection and can readily determine whether the physical facilities are adequate for the agents declared. Inconsistencies in levels or application of biosecurity precautions would indicate shortcomings in compliance, such as use of undeclared agents. (2) Physical examination of storage containers could reveal agents that are not declared, or that are kept in a manner inconsistent with declarations (*e.g.*, in larger quantities than declared). (3) Selected samples from storage can be tested to determine that they are correctly labelled. Inconsistencies in labelling would indicate need for further evaluation. (4) When people or animals are exposed or immunized to a given agent, they develop antibodies, which can easily be detected by routine blood testing. Random screening of sera from personnel or experimental animals would therefore identify which agents they have been exposed to or immunized against. Presence of antibodies to agents not declared, or results inconsistent with the subject's history, would suggest the need for further explanation. (5) One may also find inconsistencies when interviewing personnel or examining records. (6) Consistency with the stated purpose of the facilities: For example, a vaccine plant would have procedures designed to optimally protect the product (in the United States, vacine production facilities must meet the Food and Drug Administration's Good Manufacturing Practices), require precautions not needed if BW agent were the product.

More recently, a team including members from the World Health Organization (WHO) carried out a similar visit to a large government facility in the United Kingdom, and reached similar conclusions (J. Woodall, personal communication, 1992; J. Woodall and J. Melling, unpublished paper distributed at BW Experts Group meeting, Geneva, April 1992).

There is some question about whether a program such as that proposed by the FAS group, will be unduly burdensome to industry. Jack Melling has polled colleagues in the biotechnology industry in England. According to Melling, most felt that it would be tolerable as long as everyone had an equal burden so that there was a level playing field. In the United States, there may be more reservations by industry. However, most chemical and biotechnology companies are already regulated by various government agencies, with various reporting and inspection requirements. While BW inspection might impose an additional regulatory burden, our impression from trial visits was that the burden would not be excessive. Most facilities had the information needed for declarations readily available, usually requiring only some rearrangement of information they had already provided to government regulatory agencies. An inspection would also be similar to those already experienced from FDA or other government agencies. Additionally, most facilities are likely to be inspected only rarely, if at all. Finally, outside of government, even in the United States the number of facilities requiring declarations is also likely to be fairly small, on the order of several hundred, estimated (by Barbara Hatch Rosenberg and the FAS group) from tabulating FDA licensed facilities.

Although an international organization to administer the compliance regime may increase the cost of the program, the considerable benefits in objectivity, independence, and fairness weigh strongly in favor of this option. Cost would be considerably reduced if an organization such as WHO were able to help coordinate some of the efforts and expertise.

A verification program offers two types of benefits. The first, and the original intent, is reassurance. A well run program can reassure States (not absolutely, but to a reasonable degree of confidence) that activities in facilities of other States are likely to be generally consistent with their declarations. This also provides additional incentive for States to ensure that their own declarations are accurate, and assists States in monitoring facilities within their jurisdiction. Finally, the program provides a mechanism for resolving possible inconsistencies, thereby reducing misunderstanding and suspicion.

Secondly, a regular program will amass broad comparative experience, with several potential advantages. Even an imperfect verification system will provide a base on which to build, while developing improved procedures with increasing experience. Even in the early stages, the availability of comparative data can be of value to States Parties. No inspection program can guarantee that all violations or unauthorized use will be detected, but general comparisons can reassure states that they or their neighbors are not statistically outside the norm. Defining statistical norms can prevent the "arms race" mentality caused by the feeling that one is lagging behind a potential aggressor. Inspections can also provide expert unbiased advice for improving safety or efficiency of facilities or procedures. This may be especially useful for smaller States Parties. Comparative data can also help to develop improved consensus recommendations on safety procedures and improve the state of the art for handling the listed agents.

Inspection of facilities can provide valuable information, especially when combined with other approaches in an integrated coordinated program. However, because inspection and compliance assessment can only provide hints of possible inconsistencies or probable compliance, effective biological weapons control and verification requires a multiple approach. In addition, there must be additional mechanisms for investigating use, or alleged use, of BW. *Ad hoc* field investigation of alleged use has recently been discussed by Barss (1992). Barss' suggestions for the development of a standardized protocol should help to make these field investigations more effective.

To be effective, an integrated system must therefore be at least three-pronged (Table 4), including verification and inspection of facilities, epidemiologic field investigations of alleged use, and regular *global epidemiologic (health) surveillance* for outbreaks of unusual infectious disease. Intelligence services, as well as other sources, can provide information useful to all three components.

Distinguishing natural disease outbreaks from BW use or BW accidents requires both careful investigation and knowledge of local diseases and locally endemic infections. Disease surveillance and detection of BW therefore share common requirements. A global capability for recognizing and responding to unexpected outbreaks of disease, by allowing the early identification and control of disease outbreaks, would simultaneously buttress defenses against both disease and BW. This argues for expanding permanent surveillance programs to detect outbreaks of disease (Morse, 1990; Morse and Schluederberg, 1990; Wheelis, 1991), both for maximal effectiveness in monitoring BW and for humanitarian reasons. Disease surveillance systems designed to provide early warning of emerging civilian health threats (Henderson, 1992; Henderson's plan is also summarized in Morse and Schluederberg, 1990, and in Morse, 1990) would be a valuable addition to the other measures discussed, such as epidemiologic field investigations and verification protocols, and could provide information useful for identifying possible BW and for aiding BW investigations.

One major limitation of existing systems for disease surveillance is poor or inconsistent communication and coordination between different systems or agencies. Upgrading communications and response capabilities should be a priority, with networking of human and agricultural health monitoring facilities worldwide to allow rapid reporting and evaluation of disease outbreaks or other unusual occurrences (Morse, 1990; Wheelis, 1991). Additionally, good linkage between these systems and *ad hoc* investigations of alleged BW use is desirable.

Recently, such worthwhile efforts as global infectious disease surveillance networks and vaccine production programs (Geissler, 1992) have been suggested as additional incentives under

Article X (cooperative measures) of the BW Convention. One hopes these worthwhile programs benefiting world health can soon be implemented. Used primarily for public health purposes, such programs can greatly benefit both world health and arms control at relatively low cost (Henderson, 1992; Rosenberg, 1992).

Biological weapons control (history reviewed in Haar, 1991) essentially began with the Geneva Protocol of 1925 and continues into the present. The general trend has been incremental strengthening of the conventions, making each successive instrument more comprehensive and restrictive than the last. However, as many have pointed out, there is a fatal flaw in this gradualist approach: the continuing development of biotechnology makes it possible to develop new types of biological weapons and to greatly simplify the production of many others. As biotechnology continues to develop, the Biological Weapons Convention will therefore find itself in the position of fighting against obsolescence, always lagging behind new developments which often cannot be anticipated. For this reason, any attempts at control of biological or toxin weapons must be dynamic and open ended, allowing for new discoveries and inventions. Some progress has already been made towards suitable systems. The ideal verification system is not yet available, and may never be possible, but technically feasible systems available today can offer considerable reassurance at relatively low cost, while providing a base of experience to improve verification measures in the future. Given recent history, including international uncertainty about Iraqi weapons plants, it would seem perilous to delay any longer.

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Table 1. Some unique features of BW relevant to verification

- Agents easily produced using relatively simple equipment and raw materials
  - Little specialized equipment is required
  - Precursor materials often can be used for purposes other than BW ("dual-use"), and function may easily be disguised
- Few obvious signs to indicate improper activity
- Great diversity of possible agents, each usually requiring a specific detection method
- Often difficult to distinguish BW agents from other natural products
- Agent may be natural cause of a disease endemic to area, so unequivocal determination of use can be difficult
- Biotechnology is providing ways to make novel agents, difficult to detect in routine testing

Table 2. Hypothetical stages in BW product development

1.	Identification of potential new agent
2.	Procure or develop sample of agent (as seed stock) Check suitability of facilities and methods
3.	Grow or produce seed stock to token quantities (perhaps 100-1000 fold) Test product
4.	Preserve (freeze, lyophilize) in token quantities (may periodically retest or regrow to replenish supply or to prevent loss of potency)
5.	Scale up production (e.g., for weaponization, but also for vaccine, etc.) (Depending on various factors, scale up may be done in several stages)
6.	Ready product for delivery system (e.g., add stabilizers) Prepare or procure appropriate delivery system (ballistic, aerosol generators, etc. as required) Load product and distribute loaded delivery systems

Table 3. Basic features of a proposed compliance regime for BWC

(summarized from FAS, 1992; see also Appendix)

- Declarations by States
  - Includes all high containment facilities (BL4; BL3 for aerosols), all facilities with controlled agents, etc.
  - Vaccine production facilities (already included by Third Review Conference)

- Independent inspections to monitor compliance with declarations
  - To be carried out by an independent agency (Organization)
  - Some limitations on number of visits per State
  - Inspectors may examine facilities, test samples, etc.
  - Regime is add-on to confidence-building measures: Organization will also administer cooperative programs and other confidence-building measures

- Mechanism for resolving disagreements and acting in event of non-compliance (through Organization; if needed, diplomatic channels)

Table 4. Strategies for monitoring BWC: A tripartite system for BWC compliance monitoring

Component 1. Compliance monitoring regime (declaration and inspection of facilities), including cooperative programs and other confidence-building measures (FAS, 1992; Rosenberg, 1991)

Component 2. *Ad hoc* epidemiologic field investigations of alleged use (Barss, 1992)

Component 3. Global infectious disease surveillance system for health monitoring (Henderson, 1992; Morse, 1991; Wheelis, 1991, 1992)

System should network human and agricultural health monitoring resources

Conventional Arms Control and Verification for the '90s: A Broader Context is Needed

S. Stevens, L. Sullivan
Systems Planning Corporation

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Williamsburg, Virginia

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CONVENTIONAL ARMS CONTROL & VERIFICATION FOR THE '90s:

A BROADER CONTEXT IS NEEDED

by Sayre Stevens and Leonard Sullivan, Jr.

The past decade of serious arms control negotiations has been devoted to reducing the chances of the two superpower alliances fighting World War III and risking destruction of the civilized world. But even before the CFE and START treaties are ratified, the world situation has changed to the point where these strenuous and litigious efforts appear almost irrelevant: relics of a bi-polar age which ended in the virtual collapse of one superpower, and the economic weakening of the other.

One consequence of the ongoing high-tech arms race is the continued and expanding arsenals of dangerous weapons of destruction in the hands of an ever-widening circle of "second and third world" powers. It is by no means clear that the emerging, thawing, mutli-polar world will enjoy the stability associated with the frozen political landscape of the Cold War. Effective and verifiable arms control measures are perhaps even more important in the years ahead--but they are not likely to derive from extending the bi-polar efforts to date--laudible though that might be.

Although the spirit, precedent, and experience gained in CFE should be preserved and exploited, broader forms of arms control will need a break with the past and new objectives ab initio--objectives that are meaningful, viscerally responsive, and utilitarian to the expanded set of players.

It is high time to stop thinking in terms of CFE-1A, or START-2C, and start evolving a new, broader framework with applicability well beyond the obsolete and meaningless domains of US/USSR or NATO/Warsaw Pact. A more fitting context for these new efforts will almost certainly include:

a) Continuing diminution in the credibility of any CIS threat outside its own borders, as its remnants face further fragmentation, and its collapsing economy drives people--and the Red Army--into the streets;

b) Continuing decline in the relevance of NATO and the growing unwillingness of (Western) Europeans to maintain significant military forces--or pay for specialized military activities;

c) Diminishing Western concerns for technological disclosure to the CIS, coupled with increasing opportunities to purchase Russian technologies and work together with them against 3rd World threats;

d) Declining anxieties about CIS armed forces and growing concerns about real threats posed by the newer "bad actors" in the world: overarming is now seen as a worldwide--not a regional or bloc--problem;

e) Dawning recognition that the fashioning of a treaty which may be a perfect compromise, but which on the one hand lacks practical, broad-based, defineable verifiability and on the other hand permits instant and obvious circumvention, is arguably not better than none;

f) Growing focus on competitive economic development throughout the developed/ing nations which will further reduce tolerance for government spending on arms, arms control, or inspection;

g) Growing realization that the CFE agreement reflects Western interest in redressing a military disadvantage in a particular circumstance that no longer applies--rather than in genuinely limiting arms production, transfer and replacement worldwide;

h) Unexpected improvement in the ability of broader international bodies to develop straightforward, meaningful, binding agreements promptly and without legalistic obfuscation (e.g., CSCE CSBMs and UN sanctions). There is an unprecedented worldwide consensus on acceptable international behavior, human rights, and environmental abuses. A worldwide surge in political--and economic--prosperity could result;

i) Growing recognition in some political bodies that arms control depends more on trust, confidence, and assured warning than on sophmoric notions of equal numbers and watertight, but unenforcible, laws and codicils.

j) Greater understanding that the ability--and willingness--to use military forces depends far less on numbers, classes, and locations of equipment than on the unnegotiable qualities of leadership, training, operational doctrine, usable equipment technology, logistic support, command and control, determination--and national rationality;

CFE has pursued careful and selective delineation of specific hardware and operational elements whose elimination would reduce the sources of instability in opposing forward deployed forces. But the resulting demands on compliance verification may not be politically or economically affordable. New, but ill-defined, ad hoc verification criteria are emerging, such as "military significance"--on which lawyers, politicians, and military have vastly different views, and "suspicion levels" which would govern the intensity of inspections--a novel but untried approach.

Those wishing to extend and improve the current--incomplete--CFE agreement seem to want to focus on: adjusting the sub-zones and exclusion zones within the current partial areas with the specified Atlantic-to-the-Urals ("ATTU") region; more military exercise constraints; elaborate rules about temporary out-of-garrison movements; detailed composition of the forces; developing guarded entry/exit/transit points to, from, and within the region; deeper, numerically-equal cuts in "treaty limited equipments (TLEs)"; and new categories of TLEs--including purely defensive items(!).

On the other hand, those (including these authors) who believe worthwhile conventional arms control efforts should be broader, but less costly, less intrusive, less picky, and less near-term, would begin to emphasize:

- eliminating the arbitrary distinctions between verification and circumvention and concentrating on assuring that extant military forces cannot confidently or unexpectedly attack another country;
- expanding the treaty-included zones to encompass the regions and countries of Europe now excluded, all the present CIS--and beyond;
- embracing all aggressively-capable military and para-military forces, including navies, marines, air forces and internal security forces;
- monitoring TLE sales, production, and mobilization capacity--worldwide;
- focusing on complete military organizational units together with their associated TLEs, TLE-shelters, mobility equipment, and base structure;
- improving the "burdensharing" of arms control inspection costs; and
- developing a rational plan to adjust the level and intrusiveness of inspection in accordance with levels of suspicion.

We believe it is far more important and productive to increase the world's willingness to obey the spirit of arms control, and to devise inspection techniques based on presumptions of innocence until suspicions are raised in--and supported by--some suitable regional or worldwide international body. The measures--perhaps statistical--used to trigger increased surveillance would derive from the detailed provisions of the agreement, but would not constitute an exhaustive check on each provision per se.

We believe that our longer range, broader, arms control objectives should include the following ten broad, conceptual objectives:

1. Transferring the arms control/inspection efforts away from the prior NATO/Pact alliances towards more lasting regional institutions, perhaps initially CSCE-wide, but eventually, worldwide--possibly via the UN.

2. Integrating the initial efforts with the CSCE's CSBM process, procedures, and emerging facilities (such as the Crisis Control Center), and moving CSCE from unanimity- to majority-based actions;

3. Shifting the concern to operational force potential, and away from numerical equipment inventories--and hence toward tracking operational military units, their readiness, mobility, and modernization;

4. Shifting away from the continuous, fixed activity level, ritualistic TLE egg-hunt towards a graduated system of verification actions depending on the levels of suspicion produced by less complete or expensive, statistically-based "peacetime" inspection regimes. A "mobilizable verification regime" could use low altitude aerial systems, and on-site teams as definitive steps up the suspicion--and intrusion--ladder;

5. Developing non-intrusive, global surveillance systems which do not carry the possessiveness of national security stigmas and which focus more on circumvention than verification. Secretive NTM ("national technical means") must be replaced by sharable WTM (world technical means), monitored by some regional or world arms control/verification agency. An interim step towards some shared CSCE-wide technical means is overdue (perhaps an improved Eurosat SPOT program);

6. Developing WTM-cooperative, operational unit tagging systems that ease surveillance problems and work towards automation of the routine inspection regimes, (i.e., tag the flag as well as the TLEs), leaving only non-cooperative (or suspicious) targets (more likely bases, ports, or factories than individual TLEs) for persistent monitoring;

7. Concentrating on monitoring conventional force bases, using simplifying assumptions such as relating the base size to the maximum reasonable force, and perhaps relating its force readiness to the number of "unsealed", occupiable barracks and maintenance facilities. This could discourage "baggy (oversized) bases" and "baggy barracks" as well.

8. Establishing internationally-manned regional arms control inspection centers to provide continuous surveillance and warning of potentially suspicious military developments, production, or unit activity throughout their region, based on internationally-available intelligence.

9. Abandoning the bilateral goals of equal numbers of TLEs and establishing some system or convention for the "licensing"--and tagging--of allowable and militarily significant national force units (active and reserve) and production facilities (active and reserve), and then monitoring for any "unlicensed" increases;

10. Devising ways to assist and incentivize destruction (vice transfer) of surplus treaty-limited equipments which do not put the burden solely on the owner or the challenger. (For instance, Japan or Canada might agree to buy that surplus equipment and recycle it into exportable civilian goods--that might be declared duty-free imports.)

The long-range impact of this would be regularize arms control monitoring on a regional basis, and to institutionalize use of international surveillance, and "mobilizeable" verification responses. Primary surveillance means might be some kind of "verisat" system providing regular (weekly?) information on test centers, ports, factories, and military bases. "Suspicious activity" (suitably defined by treaty) would trigger enhanced short-notice on-site--or over-site--verification measures, possibly first by aircraft, and subsequently--if needed--by ground parties.

The suitable "region" might begin with some CSCE-limited area, but should eventually expand to encompass most of the Eurasian continent, including its southern "flanks" into the Middle East and Southwest Asia. A similar system might be developed for the Pacific rim, to include China. Simpler systems might eventually be found useful for the African continent--and the American hemisphere. Somehow, these regional centers might then be linked into a global, UN-operated, arms control inspection system.

Although these concepts may seem grandiose indeed, we see little reason for CFE-2 to be a continuing "refinement" of CFE-1 (and 1A). Instead, we should take a first step in a more comprehensive direction in which the past uniqueness of the superpower confrontation devolves into a broader international concern for arms control. Surely, a similar path will eventually evolve for global environmental control as well.

ABSTRACT

This paper proposes the need for an entirely new post-confrontational context for pursuing conventional arms control and verification. It offers ten specific aspects of the broader context (such as shifting from a NATO to a CSCE framework); delineates several new areas of emphasis (including verification cost reduction); and outlines ten conceptual objectives (such as graduated-response verification, the use of international technical means, and collective surplus disposition).

The paper is intended to be provocative and to stress the need to move away from the narrow past towards a broader worldwide future--which might eventually be applicable for global environmental control as well.

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SESSION II

The Interface Between Intelligence and Arms Control

Chairman
K. deGraffenreid
JAYCOR

Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

Arms Control, Nonproliferation, and Intelligence - A Potentially Beneficial Partnership

S. Mullen
U.S. Department of Energy

Prepared for:
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Hospitality House
Williamsburg, Virginia

NONPROLIFERATION: MATURING ARMS CONTROL ISSUE

25-YEAR VETERAN OF ARMS CONTROL ARENA...

- NPT INTO FORCE IN 1970
- TLATELOLCO INTO FORCE IN 1968
- IAEA IN EXISTENCE FOR 35 YEARS

...BUT ONLY ACHIEVED CENTER STAGE IN 1991

- IRAQI EXPERIENCE
- LOSS OF FAITH IN IAEA SAFEGUARDS
- BREAKUP OF SOVIET UNION
- LOOSENED COCOM AND OTHER CONTROLS ON DUAL-USE PRODUCTS

FACTORS AFFECTING GLOBAL ATTITUDE TOWARD PROLIFERATION

NPT EXTENSION CONFERENCE

- **TIGHTER SAFEGUARDS PROCEDURES?**
- **STRONGER VERIFICATION LANGUAGE?**

HEIGHTENED THREAT PERCEPTION

- **OTHER NPT CHEATERS?**
- **DE FACTO WEAPONS STATES?**
- **LESS ADVANCED NON-NPT PARTIES?**

SOUTH-SOUTH NUCLEARTRADE/COOPERATION

- **CHINA-ALGERIA, IRAN-ARGENTINA, ETC.**

ARMS CONTROL ANALOG

"INTELLIGENCE IS TO NONPROLIFERATION AS VERIFICATION IS TO ARMS CONTROL"

- NON-COOPERATIVE VS COOPERATIVE ENVIRONMENT

- APPLICABILITY OF ARMS CONTROL VERIFICATION TECHNIQUES TO NONPROLIFERATION MONITORING

- TECHNOLOGY REQUIREMENTS SIMILAR

  -- NONDESTRUCTIVE ASSAY
  -- ENVIRONMENTAL SAMPLING
  -- SATELLITE SURVEILLANCE
  -- SAMPLE ANALYSIS
  -- TRAINING AND SUPPORT (LOGISTICAL AND INFORMATIONAL) FOR INSPECTORS

POTENTIAL AREAS OF "INTELLIGENCE SUPPORT" TO IAEA SAFEGUARDS REGIME

- TIPOFFS ON UNDECLARED ACTIVITIES
- ASSISTANCE WITH TRANSLATING SEIZED DOCUMENTS
- ASSISTANCE WITH SAMPLE ANALYSIS
- ASSISTANCE WITH TECHNICAL ASSESSMENTS OF SEIZED EQUIPMENT
- ASSISTANCE IN VERIFYING DECLARATIONS

Nuclear Proliferation: The Analytic Challenge to the Intelligence Assessment Community

J. Kangas
Institute for Defense Analysis

Prepared for:
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NUCLEAR PROLIFERATION: THE ANALYTIC CHALLENGE TO THE INTELLIGENCE ASSESSMENT COMMUNITY

by Jack L. Kangas

INTRODUCTION

This brief paper argues the need for a more comprehensive analytical approach to be taken by the intelligence community as it attempts to deal with the new complexities of nuclear proliferation. During the cold war the intelligence community concentrated its efforts on the problem of vertical proliferation in the Soviet Union and tended to give only second-order attention to the growing capabilities of medium-size and even small countries to acquire a nuclear weapon capability. The problem of horizontal proliferation now confronts the U.S. across a full range of possibilities and the prospects for containing the spread of nuclear weapons are not encouraging.

DISCUSSION

The task of working out a new paradigm for the analysis of the security issues of the post-cold war period will require a sustained effort and those included in the task will need to be flexible as the analytical elements change in a dynamic security environment. At this point, there is a need for the analytical community itself to propose candidates for the analytical agenda, i.e., analytical or methodological approaches that might be developed for application to the new security environment, of which the problem of nuclear proliferation is a central part. Against this background, the following analytical perspectives might be given greater attention:

1. Plausible Contingency Analysis

There are perhaps innumerable possibilities concerning the future world of nuclear proliferation, but there is a need to try to focus on the most plausible developments. Few analysts gave early consideration to the nuclear proliferation implications of the breakup of the former Soviet Union. The early consideration of a wide range of "what if" questions might have a useful pay-off. What if, for example, the Israelis or the Indians announced that it was a nuclear power and had several hundred weapons. What difference might that kind of announcement make? Impact studies might be made here on the effect of one country's decision to go nuclear on another potential proliferate. How might Japan, as another example, react to a North Korean decision to go nuclear? In a more general sense, there would appear to be a need for a more rigorous approach to the systemic effects of nuclear proliferation world-wide rather than confining analysis to regional areas. A basic question here concerns the effects of proliferation on regional or global stability -- the meaning of stability in different contexts needs to be examined. This approach seeks to minimize possibilities for policymakers to be taken by surprise by unfolding events.

2. Proclivities, Intentions, Motivations, and Incentives

There is a difficult dimension to intelligence assessments that concerns analysis of psychological processes and orientations, a dimension that tends to be neglected as analysts emphasize the harder data of capabilities. The problem of course is that the subjective dimension can be critical in trying to understand such questions as why a country wants nuclear weapons or what it might do with them once it has them. There is an undeveloped literature in the policy sciences that addresses issues of "political culture," "operational codes," etc., and that needs to be revitalized for consideration as an analytical tool in the assessment of how nations view nuclear weapon capabilities. One analyst has noted that analysts and policymakers alike often rest their assumptions on "flimsy foundations" and that greater attention should be paid to the basis of one's beliefs about other nations' "proclivities."[1] This is a useful reminder in the assessment of nuclear proliferation, particularly with respect to those countries about which relatively limited information is readily available.

3. Potential Role of the Decision Sciences

The cold war witnessed the development of a number of useful methodologies for application to analytical problem-solving, perhaps most notably systems analysis and net assessment. A new or modified set of methodologies is required for the defense problems of the new era. One approach would be to build on some of the pioneering though often neglected work of the past in the field of the decision sciences, for example the work of

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1 Ernest R. May, (ed.), *Knowing One's Enemies: Intelligence Assessment Before The Two World Wars*, Princeton: Princeton University Press, 1986.

analysts like Herbert Simon and Kenneth Arrow. These analysts have developed a number of useful studies that deal in particular with complex decisionmaking, organizational analysis and cognitive theory. While it is recognized that there may be severe data problems in any effort to apply the decision sciences to the problems of nuclear proliferation, there is a clear requirement to test the potential pay-off of approaches that appear promising. The return on investment in the development of these and other promising analytical methodologies for direct application to the problems of understanding the processes and dynamics of proliferation could add significantly to the kind of pay-off already being derived from the investments in the development of NTM technologies. The plea here is for greater attention to be paid to analysis of the decision calculus that drives nuclear weapon policymaking in various political and cultural environments. This kind of analysis is difficult for it involves consideration of such factors as value trade-offs, selective perception and organizational contexts. Nevertheless, the growing problem of the proliferation of weapons of mass destruction warrants and perhaps demands alternative kinds of analytical approaches in order to improve our understanding of developments that could seriously threaten U.S. and international security.

SESSION III

Lessons Learned

Chairman
D. Kay
The Uranium Institute

Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

Verification Technology: OSIA Experience

H. Rhoads
U.S. On-Site Inspection Agency

Prepared for:
Conference on Arms Control and Verification Technology
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VERIFICATION TECHNOLOGY: OSIA EXPERIENCE

Harold S. Rhoads
United States On-Site Inspection Agency
Washington, D.C. 20041-0498
703-742-4584

The United States On-Site Inspection Agency (OSIA) is responsible for planning and implementing on-site inspection provisions of several arms-control treaties and agreements, including some now in effect (such as the INF, CFE and Threshold Test Ban Treaties) and some (like START and Open Skies) which are signed but not yet ratified.

OSIA's treaty experience includes short-notice inspections, such as 24-hour visits to missile bases; longer stays at elimination facilities to observe destruction of treaty-limited items (TLI); and a continuing presence at Russia's former SS-20 assembly facility 600 miles east of Moscow. When inspection teams from the Commonwealth of Independent States (CIS) (formerly the Soviet Union) come to perform similar inspections at US facilities, OSIA provides escorts and manages support functions. OSIA's field experience with a wide range of verification technologies provides valuable insights for planning future arms control treaty operations.

Equipment Categories

When discussing "verification technology," the usual focus is on inspection devices (often complex, expensive ones) used for measuring or recording Treaty-related observations. Field experience, however, shows that mission success depends equally upon other types of equipment. The inspection equipment OSIA typically uses fits conveniently into "Support," "Security," and "Mission" categories.

Support Equipment includes items for insuring the safety, health, and welfare of inspectors and escorts. This category covers a surprisingly wide range, from the exotic (radiation detectors, chemical-weapons protection, emergency medical equipment) to the mundane (parkas, notebooks, rain gear, boots).

This relatively unglamorous category is absolutely essential to team productivity and efficiency, and thus to the success of the on-site inspection regime. An inspector or escort lacking adequate cold-weather clothing, for example, will not be able to perform all treaty-required tasks under conditions commonly encountered in the CIS or the northern United States.

Because support equipment can affect the operation of technical equipment, designers have been asked to treat clothing, notebooks and the like as part of the inspection "system" and make appropriate design allowances. For example, a chemical sensor might incorporate oversized control knobs for operation with heavily-gloved hands, or large, bright displays for easy reading through a protective visor.

At the very least, new systems should be tested under realistic field conditions by operators wearing typical inspector clothing. This testing wasn't possible with one modular building, which had to be deployed on short notice to OSIA's Votkinsk portal monitoring facility in Russia following development and testing in a relatively temperate climate. When the door froze shut in a subzero snowstorm, operators discovered they couldn't apply enough force to open it because their gloved fingers wouldn't completely fit into the recessed door handle.

Security Equipment ensures the integrity of the inspection process. Inspection results have significant implications for the governments involved, justifying measures to deter or detect any attempt to "spoof" or tamper with devices used to obtain those results. OSIA currently uses tape seals, a fiber-optic cable sealing system, special carrying cases, and plastic shrink-wrap film for this purpose, but inspection system designs can include inherent security features.

One example is the calibration source for the Radiation Detection Equipment (RDE), used to differentiate between the single-warhead SS-25 missile (not limited under INF) and the treaty-limited three-warhead SS-20. Because the missiles are sealed in externally similar canisters, the differences in radiation patterns around the canister exterior provide a non-intrusive inspection technique. The RDE is kept in sealed storage in Russia between inspections, but the pre-mission calibration procedure, using a small radiation source brought in by each inspection team, increases confidence that the radiation detector is working properly and giving accurate readings.

Mission Equipment helps inspectors collect the information agreed upon during treaty negotiations to provide evidence that each side meets its treaty obligations. Mission equipment ranges from simple devices, such as a steel tape for measuring vehicle dimensions, to systems for measuring the yield of underground nuclear explosions, operated by a crew of technicians and requiring many weeks to set up.

From the user's standpoint, all Mission systems share one highly important feature: their selection and use are closely constrained by treaty provisions. Because inspectors have little flexibility with Mission equipment during field work, it is especially important for planners, negotiators, and designers to consider "operational" factors like weather, working environment, and equipment ruggedness in their planning process. With treaties enduring for decades, designers must consider the possibility that key components can become unavailable. Securing international approval for any modification to treaty-agreed equipment can require surprising amounts of time and effort.

Interdependence. While the "Support, Security, and Mission" categories provide a convenient framework for thinking about verification technology, the boundaries between them are not sharply defined. Problems in any category can easily jeopardize mission success; if the readout system for a Security device fails, for instance, that may cast some doubt on data collected with the Mission system it protects. Similarly, a problem with a piece of chemical protective gear (a Support item) could disrupt or halt all inspection work at a chemical-weapons facility.

Also, some devices perform functions in more than one category. A very simple example is the flashlight each INF inspector uses to examine missiles (Mission), avoid hazards in dark areas (Support/safety), and check seals at night (Security).

Design Criteria

Effectiveness of inspection equipment is OSIA's primary technological concern. Recruiting, training, equipping and deploying inspection teams to distant locations is expensive, and treaties strictly limit the number and frequency of visits. Inspection results must survive scrutiny at many levels of government and, in concert with information from other sources, ultimately support decisions that may affect national security. Clearly, inspection equipment must perform its required function well, and provide high confidence in the results obtained.

Reliability, one contributor to "effectiveness," deserves special attention because of its importance to the inspector in the field. Total equipment failure obviously threatens mission objectives, but an undetected malfunction could be worse. Suppose the equipment appears to work properly, but gives results outside the expected or "allowed" limits. Do the readings reflect an inspection-equipment problem . . . or something else? Diagnostic procedures, well-trained operators, and portable backup equipment sets are essential elements for any inspection system incorporating complex, failure-prone components.

The inspection environment often aggravates the reliability problem. Inspections typically occur at military bases or industrial locations featuring various combinations of cold, heat, darkness, rain, snow, wind, dust, insects and noise (electronic and acoustic). Transportation to remote sites in military aircraft, or in utility vehicles over rough roads, often exposes equipment to contaminants, shock, and vibration, requiring robust design and special packaging.

Inspectors working overseas can expect little equipment repair support from those they are inspecting because the required spare parts, tools, and technical data won't be available in remote areas. OSIA teams can (and do) bring limited sets of these items, but they complicate another design goal: keeping the load light.

Portability is a major concern for inspectors who must move both personal luggage and inspection equipment across oceans and continents to remote sites for brief inspections. Heavy, bulky, delicate items aren't just a nuisance: they pose real threats to safety and mission effectiveness. At least two OSIA inspectors have been temporarily disabled by lifting-related injuries while moving INF inspection equipment. One Russian aircraft, often used to carry US inspection teams, requires a 4-meter (12-foot) vertical lift up a ladder to load cargo when passenger stairs are not available, which is often the case.

Conversely, while lightweight inspection kits are desirable, having too many small, separate cases complicates inventory control during team movements. Most inspection trips involve at least a dozen transportation stages (buses, aircraft, customs inspections, and the like), and each stage is an opportunity to lose something.

When possible, inspection equipment should be designed to avoid using items requiring special handling. While a few OSIA missions have involved moving radioactive materials (e.g., the RDE calibration source), hazardous chemicals, and even morphine, such items seriously complicate mission planning and execution.

Training and operator qualifications are important for ensuring equipment effectiveness and reliability, and extensive training requirements impact operational schedules and overall mission costs. Several team members should be qualified to operate each item of equipment so the mission can proceed even if one specialist is unavailable for any reason. Also, the inspected party's escort team needs to understand, and sometimes even participate in, inspection operations. The ideal equipment set, from the OSIA standpoint, consists of user-friendly equipment, fully tested for ruggedness, requiring minimal explanation and accompanied with clear (preferably multilingual) instructions for field operation.

Policy context: OSIA's primary concern when considering design features of equipment for use by US inspectors is effectiveness under field conditions. However, planners, designers, and operators must be sensitive to such technopolitical issues as reciprocity (participants on each side expect a fairly precise symmetry of rights and constraints) and precedent (a seemingly innocuous action can have unexpectedly far-reaching consequences).

Planners and equipment designers must also consider export controls, dual-use technologies, and intrusiveness when selecting tools for various inspection and support applications. Export controls apply because treaties generally allow the inspected party liberal rights to detailed study (including engineering drawings) of every item of equipment the inspecting party uses on its territory; many items are simply unavailable for use by OSIA inspection teams for this reason.

Inspected parties may prohibit or restrict devices incorporating "dual-use" technologies: those which might perform unauthorized as well as legitimate functions based upon treaty provisions. Electronic devices, even relatively simple ones, are affected most often. For example, OSIA inspectors may bring audio cassette players for personal use on some long-duration INF inspections, but units with any recording capability are strictly prohibited.

The dual-use issue is related to the "intrusiveness" problem: some modern technical devices, while ideal for a particular treaty activity, might reveal more detailed information than the treaty negotiators intended. For example, Open Skies aerial cameras must not perform too well, exceeding resolution limits established during treaty negotiations. The Threshold Test Ban Treaty incorporates numerous provisions (including an "Anti-Intrusiveness Device" for certain critical components) whose sole purpose is to protect each side's nuclear design secrets. Intrusiveness concerns lead to an unusual challenge for design engineers, who must take care to meet, but not to exceed, certain key design performance specifications.

Lessons Learned

Keep it simple. As complexity increases, so do problems with reliability, portability, and operator training. The two most frequently used items for INF inspections are also the simplest: flashlights and tape measures. Among OSIA inspectors, the steel tape measure wins first prize because, unlike the flashlight, it requires no batteries, has no bulbs to burn out, and weighs less.

Anticipate problems as complexity increases. Some treaty requirements are inherently technology-intensive. (So far, we have no satisfactory method for determining the yield of an underground nuclear explosion using only flashlights and tape measures.) When complex procedures and equipment are essential to mission accomplishment, everyone involved must make allowances for additional inspector training, operational delays, and equipment failures.

Know the operating environment before investing. Like simplicity, this is an "if possible" objective because fast-breaking world events driving verification requirements may not allow time for extensive site surveys, field testing, and design adjustments. When time is available, such preparations can dramatically reduce implementation costs and minimize operational problems.

Involve users early and often. The people who will apply verification technology in the field can provide valuable perspectives for decision-makers, negotiators and equipment designers.

Lessons for Guiding Future Verification Requirements

R. Scribner
Georgetown University

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Lessons of Arms Control Verification Experience: Guidance for the Future

Richard Scribner
Assoc. Professor
School of Foreign Service
Georgetown University
Washington, D.C. 20057

ABSTRACT

Rapidly changing international relationships, varying degrees of cooperation, and the extended range of arms control stimulate new verification requirements. Some new requirements may be more stringent and probably most others will be less so. New agreements in the strategic area will build their verification regimes on the START framework. As this happens, what standards of verification certainty and compliance should apply? Whether a variation from agreed limits makes a military difference has been the measuring rod. While attempts to quantify that rule have been made for conventional weapons agreements, it has never been precisely quantified in nuclear cases. Some types of arms control benefit from the greater acceptance of intrusive measures, but confront other political, procedural, technological and legal stumbling blocks. The verification and compliance lessons of the recent past as well as those of the last decade may not yet have been fully assimilated. This paper reviews the verification and compliance principles and experience of the past 12 years with special attention to the experience of the last 6 years. Assuming a degree of linear extrapolation from today's arms control experience to the next decade of challenges, it draws out some of the "old" as well as "new" lessons that may help guide both strategic and non nuclear as well as bilateral and multilateral arms control in the future. This paper also examines whether some of the traditional guiding principles of verification need modification under the new and changing circumstances, and suggests that, in fact, much of the next decade's arms control initiatives may, in fact, be undertaken in a rather different fashion than has been the experience to date.

INTRODUCTION

Remarkable changes have occurred in arms control over the past 5 or more years, all made possible by the even more remarkable changes that have taken place in the former Soviet Union. The impact of the changes within the Soviet Union over the past seven years on arms control and underlying the political relationship between the US and the Soviet Union, were only dimly glimpsed by most observers at the outset of those changes. They, of course, started with the leadership of Mikhail Gorbachev in March of 1985, continued through a US-Soviet summit meeting resulting in the signing of the INF Treaty in June of 1987, and come to fuller fruition in 1989 with the crumbling of the Warsaw Pact and the fall of the Berlin wall. These and other events led to political change in the U.S.-Soviet relationship that was outpacing both the Conventional Forces in Europe negotiations and the START negotiations.

Not only have there been leaps forward in what reductions and operational agreements in strategic and theater nuclear and non nuclear arms control, but also there has been a revolution in what verification measures are in fact negotiable. For example, prior to 1985, U.S. insistence on on-site inspection was virtually a "non-starter" in negotiations with the Soviet Union.

The premises of this paper are the following. The standards, approaches, and technologies of arms control verification thought necessary for the bipolar world existing in 1985 and the 35 or more years before, are not the same now. Over the past 7 or so years we have learned (or relearned) many lessons about arms control verification that may make future efforts easier. In some cases compliance will not be ensured to the same higher standard deemed necessary in agreements with the Soviet Union during the cold war years. In other cases, compliance may be required to an even higher degree, and measures taken to ensure that the requirement is met rather severe.

Some of the questions one could ask about the lessons from our verification experience, include the following: (1) How has the climate for and the priorities for arms control and its verification requirements changed? and (2) What are the lessons (about verification and compliance) that can we draw from our experience of the last 5 to 7 or more years? What guidance may we extract from these lessons for implementing START and its follow-on deep cuts, follow-on conventional weapons limits, and further implementing non-proliferation regimes? Finally, (3) what lessons from either the last 6 years of arms control verification or more generally from our history over the last 30 years should be "remembered" as we enter what is presumed to be a "new world order."?

To examine these questions and others, this paper will review what in fact have been some of the problems of verification and compliance; how serious they have been; what might be learned from them; and what lessons may be drawn from the verification and compliance experience of the period 1986 to mid-1992.[1]

FROM "IS ARMS CONTROL DEAD?" TO "A NEW WORLD ORDER"

Among the political issues slowing arms control progress in the period from 1983 to 1985 and to a lesser extent until 1987 was the great and to some extent exaggerated public attention given compliance issues.[2] In fact, prospects generally looked so bad for arms control progress in those years that several articles were written all basically asking the question "is arms control dead?" The somewhat overblown "non-compliance" issues of the period were raised mainly by the the U.S., although each report out of Washington was usually soon followed by a Soviet counterpoint charging, generally unconvincingly, the U.S. with noncompliance.

Viewing the Soviets as prone to circumvent arms control agreement compliance and therefore reluctant to engage in more agreements, the first

Reagan Administration "hung tough" on compliance issues basically seeking Soviet apology and evident behavior reversal before they were willing to seriously engage in more agreements. Arms control advocates, it was charged, were simply interested in the agreements for there own sake, notwithstanding the long-standing rationale that arms control could make important contributions to national security interests.[3] Even today, some of these attitudes remain.

For some in the Reagan Administration, who had deep reservations about any arms control agreements with the Soviets and no desire to see the U.S. forces limited in any way, charges of verification inadequacy may have been a handy shield behind which to hide their true thoughts. Inflated charges of Soviet non-compliance served to bolster the U.S. fears of Soviet cheating. Repeated assertions that verification approaches were inadequate may have conveyed to the public that arms control proposals such as curtailing anti-satellite weapons and others were intractable problems. Recent history has shown (again) that verification per se need not be a barrier to implementing arms control initiatives.

As momentum for arms control picked up in the second half of the1980s (see Table 1), the U.S. introduced more and more complicated verification proposals for substantial reductions of weapons, developing new confidence building measures, dealing with problems of mobile missiles, and eliminating variations of weapons that could be particularly destabilizing. The complexity of some of these schemes - such as elaborate tagging, tracking, and recording systems - , at least as applied to nuclear arms control, may have already peaked. It may be that both Russia and the U.S. are less interested in such complex systems now and more interested in simpler arrangements that can accomplish the same end.[4]

TABLE 1. Some Arms Control Events/Experiences of the Last 6 years

Conference on Disarmament in Europe (Stockholm Accord)
Intermediate Nuclear Forces (INF) Treaty
Nuclear Test Treaties (TTBT & PNET) Ratification
Soviet Test Moratorium
Bilateral Chemical Weapons Agreement
Conventional Forces in Europe (CFE) Treaty
Chemical Weapons Convention Negotiations
Sea Launched Cruise Missiles (SLCMs) Statement/ Not Part of START
Iraq and UN Resolution 687 Implementation Experience
U.S. & Soviet Unilateral and Reciprocal Initiatives of the Fall 1992
Strategic Arms Reductions Talks (START) Treaty
South Africa Signs NPT
France and China Announce Intention to Sign NPT*

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* The People's Republic of China deposited its accession to the NPT on March 9, 1992.

The thinking about such complex verification measures helped lead to and was further stimulated by (1) the completion of the 1986 multilateral Conference on Disarmament in Europe agreement establishing observer on-site inspection; (2) the 1987 bilateral Intermediate Nuclear Forces agreement establishing verified data exchange, scheduled on-site inspections of declared facilities and operation of a perimeter to portal monitoring system; (3) the many proposals for dealing with the thorny verification problems such as verifying reductions in nuclear tipped sea-launched cruise missiles, TLAM-Ns; (4) the prolonged START negotiations which early on had established that the strategic nuclear arms reductions agreement would not only embody the verification measures, but also would go beyond those measures in extent and complexity in order to ensure compliance with the reductions of warheads required by the agreement; and (5) the complexity and size of the treaty limited items to be controlled by the results of the negotiations for the Conventional Forces in Europe.

Since 1987, and particularly since mid-1991, implementation of verification measures in the arms control sphere involving the former Soviet Union and the U.S. and their pact or former pact nations, as viewed from a U.S. perspective have gone remarkably well. This is true notwithstanding some troublesome problems and early fears regarding Soviet behavior and intentions, some early confrontational misunderstandings, and other problems.[5] On the other hand, while extremely intrusive and ultimately effective monitoring has occurred in connection with implementing UNSC Resolution 687, actual Iraqi compliance and good faith cooperation has been nothing short of distressingly poor to date.

PROBABLE FUTURE ARMS CONTROL AGREEMENTS AND VERIFICATION NEEDS

Before considering the lessons of past arms control verification behavior and lessons for the future, it may be useful to review possible future arms control initiatives in several categories, e.g., strategic bilateral, multilateral non-proliferation, etc.

There are two major areas for future arms control initiatives. First, there is a quite considerable "unfinished bilateral" nuclear and conventional arms control agenda. This combination I have called "strategic plus." It is, of course, not likely that this arms control agenda will any longer simply be bilateral. It includes but is not limited to those arms control initiatives between the US and Russia as well as at least parts of other nations of the former Soviet Union and some of its former Pact members. There is as well as a growing regional and non-proliferation arms control agenda.[6] It is this large, pressing non-proliferation agenda that will be the dominant aspect of the future arms control agenda.

The unfinished nuclear arms control agenda has many dimensions including resolution of ambiguous policy and doctrinal issues. It includes continued bilateral reductions and security assurances with Russia; continued openness and nuclear control assurances with all of the former Soviet States involved with nuclear weapons; multilateral talks on halting the modernization programs of all declared nuclear weapons states; finishing the Conventional Forces in Europe agreement; and negotiation of a Comprehensive Nuclear Test Ban. It may also include such areas as limiting or banning anti-satellite weapons, enhancing early warning notifications, and limiting or banning defensive weapons in space. Table 2. lists some of these possibilities.

TABLE 2. Some Elements of the "Strategic Plus" Arms Control Agenda

Agreement to Reduce Strategic Nuclear Weapons to About 3000 Each
A. Reciprocal Strategic Reductions Within the START Framework
B. Reductions Including Banning Land Based MIRVs
C. Reduce Warhead Number per SNDV and Separate from SNDV
D. Agreement to Eliminate Counterforce Nuclear ICBMs
E. Enhanced Early Warning and Other CSBMs

Multilateral Understandings to Halt Nuclear Modernization Programs

Full Extension of Limits to Airborne and Naval Nuclear Weapons
E.g., Reciprocal Agreements on Airborne Tacticals in Europe

Agreement on a Test Ban Treaty (VLTTBT or CTB)
A. Comprehensive Test Ban or Agreement on Small Annual Quota
B. Fissile Material Production Ban
C. International Fissile Material Storage Facilities

Further Reductions for Stability of European Conventional
A. Complete Open Skies
B. CFE Follow-on: CFE 1A and 2
C. Greater Openness and Transparency; Intelligence Sharing
D. Subregional Arms Control: Disengagement Zones; Etc.

Defense and Space
A. A Ban on Anti-Satellite (ASAT) Weapons Treaty
B. Anti-Tactical Ballistic Missile (ATBM) Limits
C. Renegotiate the ABM Treaty

If the "new world order" and the concomitant way in which the U.S. and the Russian deal with each other are as dramatically different as some imagine, one might be cautious about linear extrapolations of the nature and kinds of future agreements. An increasingly friendly and cooperative relationship between the two countries and full transparency within Russia, could lead to a variety of much less formal arrangements with verification arrangements handled in a casual and more ad hoc fashion. Comparatively little concern might be expressed about the level of compliance confidence from these measures, since compliance would be virtually ensured in other ways.

Efforts to deal with proliferation and regional security issues need to be given not only higher priority and greater attention, but also further shaped by two decade's experiences of implementing the nuclear non-proliferation regime and more recently of attempting to force compliance in Iraq. The list of areas is well known: A. Nuclear; B. Chemical/Biological; C. Ballistic; D. High-Tech Conventional; and E. Arms Transfers. Table 3. lists some possibilities.

TABLE 3. Some Elements of the Non-Proliferation Arms Control Agenda

Improving the Nuclear Non-Proliferation Regime
- Lessons of Monitoring Iraq and its noncompliance
- IAEA improved inspections
- IAEA Special Inspections
- Test Ban understanding
- 1995 Non-Proliferation Treaty renewed and strengthened
- New Nuclear Free Zones

Regional Arms Control and Security
- Confidence and Security Building Measures(CSBMs)
- Transparency arrangements

Chemical Weapons Convention Implemented
- Shift from anytime/anywhere inspections to limited access

Improving Biological Weapons Restraints
- Verification may continue to be a problem

Completing a Ballistic Missile Non-Proliferation Regime
- Dealing with dual use of space launch vehicles
- Barriers to strengthening the missile technology control regime
- Monitoring will be complex and incomplete

High-Tech Conventional and Other Arms Transfers Arms Control
- Supplier restraints; leading by example?

Dealing with this matters will require operational measures of several kinds stemming from two insights: (1) the fact that the strategic plus and regional or nonproliferation arms control agendas are interconnected in a number of ways; and (2) effectively dealing with the proliferations problem areas will require strengthening several dimensions of regional security as well as the various non-proliferation regimes. That is, it will require strengthening the norms; domestic policies and domestic and international laws; cooperation among countries to control distribution and sales; effective international monitoring; and systems of both sanctions and encouragements.

Within the next year, we may see some of these elements quickly implemented through simple agreements. They would include, in the strategic plus area, further strategic reductions with the START framework, further conventional reductions, and some agreement regarding nuclear tests.[7] The experience of monitoring Iraq under the guidelines of the UN resolution may well lead to strengthened IAEA monitoring. A chemical weapons convention may also be implemented.

SOME VERIFICATION LESSONS OF PERIOD FROM 1972 TO 1986

In the past, verification demands in the U.S. were perhaps over-elaborate because they were driven by the fear of Soviet cheating and supposed resultant advantage. The ideological differences, international actions, and mutual distrust had propelled both countries to acquire ten of thousands of nuclear weapons and build up to very large numbers their respective Pact's forces of advanced conventional weapons. A closed and secretive Soviet Union was deemed by many likely to cheat on arms control agreements if it could get away with it. Worst case scenarios demanded that the US have the best monitoring situation possible including substantial redundancy to achieve the highest confidence that the requirements of an agreement were being complied with. Similarly stringent monitoring is required now in Iraq.

During the 1970s, the measure of "adequate" verification was whether such a regime prevented or gave timely warning of "militarily significant" variations in agreed levels to go undetected. While it was recognized that verification can never be 100% risk free, the risk that was allowable was, in fact, to be as small as possible and in any event probably actually less than would allow even a politically significant difference.[8] Such an operational concept was embodied in what became known as "effective" verification.

The official governmental view as of 1979 was that by-and-large, the Soviets had complied with the major provisions of then existing arms control agreements. While there had been a few annoying problems with Soviet compliance and a degree of difficulty in dealing with issues that did arise, the process had worked and existing agreements were be satisfactorily maintained. Table 4. summarizes some of the fundamental elements of verification as objectively understood about 1979.

That view changed abruptly as the Reagan Administration got underway. In 1983, the Administration released the first of several "noncompliance" reports accusing the Soviets of a "pattern of violations" and listing multiple violations, "probable" violations, and "possible" violations. In fact, if one reviews the past twenty years of U.S. the approach to compliance resolution with the Soviets, it is a gross oversimplification but essentially correct to characterize it in three periods as follows: A. '72-'79: compliance issues <u>can</u>

be worked out; B. '80-'86: compliance issues <u>can't</u> be worked out; C. '87-present: compliance issues <u>will</u> be worked out.

TABLE 4. Some "Old" Verification and Compliance Principles

Verification:

Includes monitoring, assessment of verification, & compliance forum; what to do about noncompliance is a separate political matter.

100% Verification not possible to attain.

Criteria of detecting militarily significant variations. (Although verification predominantly a political issue.)

NTM is essential.
OSI needed for some agreements.

Negotiate only what you can verify with high confidence

Compliance:

100% compliance is not possible to determine.

Principle of full compliance essential
- A. However, questions will arise
- B. Need mechanisms to resolve & politically defuse

What to do in the face of a recalcitrant violator is not clear
Question remains: "After Non-Compliance, What?"

Non-Compliance Real or Perceived Requires Political Management

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To many in the Reagan Administration (at least in its first four years), the Soviets had cheated extensively, they probably were continuing to do so, and they will probably cheat on any future agreements, therefore only if we can negotiate "ironclad" verification measures (and they recant on their previous non-compliance) will the US consider any new arms control agreements. To some observers - perhaps those more interested in using arms control to reduce east-west tensions than some in the Administration who were more interesting in confronting and if possible turning back perceived Soviet advantages - the combination of publicly accusing the Soviets of massively cheating and refusing to negotiate unless the Soviets agreed in advance to verification measures that they had never previously allowed to be negotiable, seemed a sure fire method to scuttle any hopes of achieving any arms control agreements. Ironically, in retrospect they were wrong because the Soviet Union changed.

The notion that not only can the U.S. not trust the Soviets, but also that they will cheat anytime they can led many in the Reagan Administration to think that everything possible was needed in verification and even then the U.S. still couldn't be sure. Because of a frustration with the seeming looseness of "adequate" verification criteria, the Reagan Administration came up with a new terminology and concept, "effective" verification. Under this view, for example, on-site inspections, which were previously thought to be necessary for some types of agreements, became essential for effective verification of most agreements. There were some legitimate needs for OSI, although it seemed that at times the Reagan administration was requiring it in areas where it was not needed. Certainly, if warhead loadings on missiles were to be reduced, national technical means alone would be inadequate for the task. The difference between adequate and effective has never been made clear although the latter term carried with it a greater degree of stringency and a kind of "our verification will catch the culprit and make him pay" approach. In an article as recent as 1990, former head of the Arms Control and Disarmament Agency Kenneth Adelman said verification is "hollow (and) without the means to punish non-compliance."[9]

TABLE 5. Contrasting Views on Verification Requirements

Traditional Bilateral

- A. Must have (adequate or effective) verification criteria
    - A. Requires redundant & thorough verification means
    - B. Requires high confidence of compliance

- B. Risk due to a significant variation from treaty limits means a military significant difference, for examples,
    - A. Small variations with large military significance require high confidence
    - B. Deep reductions in strategic weapons will require very stringent verification regimes

Alternate View

- A. One's view of the adequacy of verification is highly dependent on one's view of the other party's (i.e., Soviet or Iraqi) behavior and levels of cooperation and transparency. That is, the required adequacy (or effectiveness) of verification is dependent on political climate as well as military risk.

- B. Verification is only a means of ensuring compliance and helping to maintain the viability of an arms control agreement. Its adequacy is only one criteria that should be used to evaluate whether an arms control agreement is in the net U.S. interests.

Uncertainty is not the same as risk and yet they were often confused. Over the last decade and even today it has not been rare to hear someone assert something like, "we can't verify that (some aspect of an arms control proposal) and therefore the risk of entering into this agreement is too great."[10] The conclusion may or may not be correct, the approach on which its is based is seriously flawed. If it were based on an estimate of (1) how likely specific numbers of such weapons are to go undetected, coupled with (2) a comprehensive and systematic estimation of the strategic threat such an eventuality could pose, and (3) compared or balanced against an equally comprehensive and systematic evaluation of the security expected from the agreement as well as of the security situation without it, then there would be a basis for estimating risk and a basis for such a statement. unfortunately, such assertions are often casual and not based on any systematic evaluation and comparison.[11]

SOME GENERAL LESSONS OF THE PERIOD FROM 1986 TO 1992

The lessons we have so far seen, from the limited experience to date, of how the new verification regimes are working may be grouped in the following categories: A. cooperation, B. missed opportunities, and C. the mixed lessons of non-proliferation compliance and progress in strengthening regimes. Cooperation has replaced fear of cheating in the strategic plus area. The climate in which to view cooperative verification measures with Russia has dramatically changed so that now (1) There are fewer difficult problems and more business as usual;[12] and furthermore, (2) as cooperation and transparency increase, the need for stringency decreases. In the operation of OSIs as well as in various dimensions of operation arms control, valuable precedents are being established and yet it seems that the vision, leadership, and sense of urgency to fully utilize the current opportunities for arms control initiatives is lacking. Finally, there has been mixed progress in the stemming different kinds of weapons proliferation. There has been generally more good news than bad in the nuclear non-proliferation arena and promise of progress on the chemical weapons convention while ballistic missile and arms transfers problems resist effective control. The lessons of the UN Iraq experience in nuclear proliferation control are at odds with what has been accomplished on most other fronts with mainly diplomatic efforts.

Effective regimes in each non-proliferation case must include, not only the basic elements of norms, domestic and international laws, and sanctions and benefits, but also comprehensive international cooperation, the rule of transparency, degrees of intrusive inspection, and accepted aggressive international monitoring. Furthermore, resolving some of the issues on, say, the Indian Subcontinent may require movement by the US on some issues that so far it has not been willing to embrace such as a Comprehensive Test Ban.

There are several general lessons - verification lessons and others - available from the Iraq experience. First, the situation that has developed in implementing UNSC Resolution 687 highlights the difficulty of monitoring when a country is determined to evade and uncaring about world censure. Furthermore, it points out how difficult it would be to verify without on-site inspection. Of course, NTM and the U-2s have been very helpful, but they would be inadequate without the ground search. Not only does OSI provide valuable information, but also the two methods, remote sensing and OSI, reinforce each other. Monitoring is most effective if one combines remote sensors with OSI. For example, one can reduce the number of (relatively expensive) OSIs required by judicious combined use of remote sensing. However, it is clear that sensors can't substitute for challenge inspections.[13]

Other lessons include the importance of independent logistics support inside the monitored country, the critically of broad political support, and the implications for how the "regular" inspections of international agencies must be conducted in the future. Simply stated, not being dependent on the host country for food, transportation, and communications is important to get the job done right. As was amply illustrated during times when the Iraqi government and/or military seemed ready to confront the inspection teams, OSIs must be politically well supported.[14] Finally, it clear that in the case of nuclear inspections the IAEA needs to exercise the challenge of "special inspections" power that already exists in its charter.

The following table summarizes some of the lessons of the last 6 years.

TABLE 5. "New" Verification and Compliance Lessons

Verification

OSIs working well; continued emphasis on the selection & training

Affordability is a function of international tension

In the future, more emphasis on lower-tech, low cost, simpler systems

Don't ask for something you don't want to implement or receive
Lesson of CWC "Anytime/Anywhere"
Lesson of CORRTEX for Regular Monitoring of TTBT

Compliance

Strategic Plus
Compliance is not without problems, but it seems to be working well: outcome is dependent on continued cooperation and transparency.

Non-Proliferation
Iraq experience and other experience provide contradictory lessons; experience suggests that highly intrusive, well supported monitoring may be required at times in the future.

In summary, some the key lessons are the following:

1. On-site inspection between the US and the former Soviet Union has worked better than most observers expected.[15] The fundamental reason for this are the democratic changes in the new republics and the consistency of US policy to date.

2. While the burden of very intrusive monitoring falls heavily in the case of the CFE treaty, based on the INF and CDE experience to date one can anticipate that if will be accomplished with the same degree of success.

3. The experience to date of the INF's compliance forum, the Standing Verification Commission (SVC), suggests that such compliance forums can work much better than we previously expected.[16]

Some types of especially useful improvements in verification and monitoring will include, generally, continued and readily accomplished OSI involving more countries, and regional security regimes enhanced by increased transparency and predictability. In non-proliferation regimes, in particular, wider sharing of intelligence will help as countries try to deal with, say, a future Iraq.

OBSERVATIONS AND CONCLUSIONS

One of the lessons of the MBFR/CFE and START experience as well as a result of the changing world order is that in the future, there will likely be more attention to less complicated treaties. Future treaties or agreements will be multilateral and parties will want them negotiated quickly. There will be much more cost consciousness involved in formulating the agreements and in implementing their verification requirements, except in those cases, such as Iraq, where costly intrusive monitoring is clearly required.

Increasing emphasis on transparency between adversaries will be the lead verification approach in regional security packages. These packages will include a broad range of confidence and security building measures (CSBMs); more data sharing; and less emphasis on new high-tech detection.

The experience of the U.S. in more than one arms control arena, but particularly with the Chemical Weapons Convention talks, leads to the conclusion that the world is not ready (and, in particular, the U.S. is not ready) for anytime/anywhere on-site inspection.

Other conclusions include the following: (1) while high tech remote sensing and other detection methods will continue and improve and monitoring packages will be further refined, there will be reduced attention to complicated high tech approaches to surface monitoring characterized by complicated tagging schemes and the exotic systems as were envisioned for, say, the verification of limits on SLCMs; (2) economic concerns will dominate considerations of "how much verification is enough?", unless there is clear evidence of a large risk and demonstrated recalcitrance; (3) verification standards will generally (but not always) be lower; and (4) given the current political climate, if the US and Russia reduce to about 3000 strategic nuclear weapons, present verification requirements and monitoring within the START framework will be adequate to provide confidence in compliance.

Among the possible questions for future study are the following: (1) With increasing transparency and cooperation with and among the states of the former Soviet Union, is there demonstrated reduced need for OSIs? (2) In the experience of implementing UNSC Resolution 687, has there been more and useful intelligence sharing and are there indications that it will continue and even be applicable to other regions? and (3) Are there any particularly promising new monitoring technologies or approaches?

In the case of the INF treaty and perhaps also the CFE agreement, the exchange of baseline date and the right to directly verify is proving over time to be important not only to the particular agreement for which the exchange takes place, but also for verification intelligence assessment generally. As the U.S. gets more and more verified data, which it can cross check with its other sources and against each successive set, it becomes more likely that any inconsistencies that might exist between different provided data sets and independent intelligence estimates will show up. That is, if over time no inconsistencies show up, the U.S. intelligence community will become more and more confident of the overall validity of the data sets.[17] This type of improved intelligence assessment also applies to other arms control areas as well. In the future there well have to be more negotiated (and simply agreed) cooperative measures to enhance the ability of each side to verify the other's compliance. As in the past, it will require careful planning, creative negotiation, clear understanding, and a commitment by all sides to make the arms control agreements work.

The over-riding problems in verification for the future probably will be much less technical and more political, as the SLCM, CORRTEX, CDE, INF, CFE, and START examples illustrate. Near exact counting with few uncertainties, may not be possible nor desirable in some useful potential agreements. This suggests that different criteria for verification will have to be fully accepted if future limits are to be negotiated and implemented.[18]

In the future, verification standards will frequently be lower than in the past and how compliance issues are dealt with will be case and political climate dependent. Some agreements that are clearly valuable such as reciprocal understandings that remove nuclear SLCMs from all naval vessels, but for which verification doesn't meet previous standards, may require accepting lower certainty in verification when the risks are relatively low and manageable and the benefits of the agreement substantial.[19] Isolated cases of recalcitrant violators will need special handling. Timely identification of such violators will be enhanced by intelligence sharing. Further progress in many difficult arms control areas may be possible only if policy makers and the public clearly understand these distinctions.

FOOTNOTES

1. I am grateful to the following individuals who discussed with me aspects of the issues presented in this paper: James Blackwell, Robert Galluci, Sherman Garnett, James Goodby, Sidney Graybeal, David Hafemeister, Gene Johnston, Jack Mendlesohn, Don Stovall, and Gregory van der Vink. I am particularly indebted to David Hafemeister for the resources he provided to me and the many comments and suggestions he also provide. I am also grateful to John Whalen for the assistance he provided in gathering documents for me.

2. See for example, The Verification Challenge, Richard Scribner et al., Birkhauser, 1985.

3. See for example, The Report of the President's Commission on Strategic Modernization (The Scowcroft Commission), April, 1983 and March,84.

4. For example, the much touted CORRTEX nuclear test yield verification system does not give better results than seismic and inexpensive and complicated. It appears that Russia is unlikely to use the option because of expense and the U.S. may now only use it rarely for initial calibration purposes.

5. For example, as recounted by Don Stovall in connection with the early Stockholm Agreement inspections, and, as pointed out by David Hafemeister, the muddled issue of the 72 SS-23s that the US says are in the INF Treaty and the Soviets say are not. "The Stockholm Accord: On-Site Inspections in Eastern and Western Europe," Don O. Stovall, Arms Control Verification & the new Role of On-site Inspection, Eds. Lewis A. Dunn with Amy E. Gordon, Lexington, 1990, p. 15.

6. See for example, "Dismantling the Arsenals - Arms Control and the New World Agenda," Jack Mendelsohn, The Brookings Review, Spring 1992, p. 34.

7. Since this paper was written, U.S. President George Bush and Russian President Boris Yeltsin agreed in mid-June 1992 to implement new deep cuts in strategic weapons and to eliminate MIRVed missile systems.

8. While military significance and political significance are generally imprecisely defined in actual practice, there are various working definitions for the former in conjunction with the concept of timely warning. In fact, during the Cold War it was often the political significance, when there was no effective change in actual military capability, that had to be managed to satisfy domestic constituencies.

9. "Why Verification is More Difficult (and Less Important)," Kenneth Adelman, International Security, Spring 1990 (Vol 14, No. 4), p. 141. Such a view ask verification to include the political judgement call of appropriate response to noncompliance.

10. For example, this was the case with proposals for measures to ban or limit anti-satellite weapons. In fact, much could be done and readily verified, although in the climate of the times, a full ban might not have been completely verifiable. In this and other similar cases the perfect was the enemy of the good. Limited and questionably effective Soviet ASATs could have been halted and critical US space based assets secured. While the present Russian US relationship requires no urgent attention to that arms control measure, looking down the road to the time when other countries might try to acquire such capability, it is still a desirable arms control measure.

11. "The Future of Verification," Richard A. Scribner, Harvard International Review, Vol X, No. 6, August/September 1988, Cambridge MA, p. 27.

12. Even as there may be more chaos in the former Soviet Union states and therefore one may anticipate more compliance problems arising from confusion or ignorance, nonetheless preliminary evaluation suggests that this statement is true.

13. Interview with Robert Galluci, U.S. Dept. of State.

14. Ibid.

15. In fact, less than 1% of the INF inspections run into problems. See, Statement on The Conventional Forces in Europe (CFE) Treaty by Gen. Robert W. Parker, Dir., The On-Site Inspection Agency, before the US Senate Foreign Relations European Subcommittee, July 25, 1991. Also from discussions with James Goodby, David Hafemeister, and Don Stovall.

16. Interview with Gene Johnston, US ACDA.

17. Scribner, 1988, p. 23

16. Ibid., p. 136

17. Ibid., p. 137

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GLOSSARY

ABM	Anti-Ballistic Missile; often refers to permanent part of the 1972 SALT I Treaty.
ACDA	The U.S. Arms Control and Disarmament Agency.
ASAT	Anti-Satellite weapons; e.g., either land-based or space-based weapons.
ATBM	Anti-Tactical Ballistic Missile; as opposed to a strategic BMD weapon.
BMD	Ballistic Missile Defense

GLOSSARY (continued)

CDE	Conference on Disarmament in Europe; also known as the 1976 Stockholm Accord.
CFE	The Conventional Forces in Europe Treaty, ratified by the U.S. Senate in mid-1971.
CORRTEX	Correlation of Radius versus Time Experiment; a highly intrusive method of measuring the yield of underground nuclear explosions.
CSBMs	Confidence and Security Building Measures.
CTB	Comprehensive Test Ban; a proposed agreement banning all nuclear tests.
IAEA	The International Atomic Energy Agency.
INF	The 1987 Intermediate-range Nuclear Forces Treaty.
MIRV	Multiple Independently Targetable Re-entry Vehicles.
NPT	The 1970 Non-Proliferation Treaty.
NTM	National Technical Means; unilateral technical intelligence collection.
OSI	On Site Inspection.
PNET	The 1976 Peaceful Nuclear Explosions Treaty; limits yields to 150 Kt. See TTBT.
SLCMs	Sea-Launched Cruise Missiles.
SNDV	Strategic nuclear delivery vehicle
SVC	The Special Verification Commission; the INF Treaty compliance forum.
TLAM-N	The version of the Tomahawk SLCM with a nuclear warhead.
TTBT	The 1974 Threshold Test Ban Treaty; limits underground explosions to 150 Kt.
UNSC	The United Nations Security Council.
VLTTBT	Very Low Threshold Test Ban Treaty; would limit yields to less than 5 Kt.

Constitutional and Legal Implications of Arms Control Verification Technologies

E. Tanzman, R. Haffenden
Argonne National Laboratories

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CONSTITUTIONAL AND LEGAL IMPLICATIONS OF ARMS CONTROL VERIFICATION TECHNOLOGIES

United States law can be both a help and a hindrance to the use of instrumentation as a component of arms control verification in this country. It can advance the general use of sophisticated verification technologies where such devices are consistent with the value attached to privacy by the Fourth Amendment to the United States Constitution. But law can hinder reliance on devices that cross this constitutional line, or where such technology itself threatens health, safety, or environment as such threats are defined in federal statutes. The purpose of this conference paper is to explain some of the lessons that have been learned about the relationship between law and verification technologies in the hope that law can become more a help than a hindrance.

This topic will be presented in three parts. In order to start with a common understanding, Part 1 will briefly describe the hierarchy of treaties, the Constitution, federal statutes, and state and local laws. Part 2 will discuss how the specific constitutional requirement that the government respect the right of privacy in all of its endeavors may affect the use of verification technologies. Part 3 will explain the environmental law constraints on verification technology as exemplified by the system of on-site sampling embodied in the current Rolling Text (CD/1116) of the Draft Chemical Weapons Convention. Of course, the opinions expressed here are those of the authors alone.

1 HIERARCHY OF TREATIES, DOMESTIC LAWS, AND THE CONSTITUTION

When President Bush uses the phrase "new world order" to capture a vision of international cooperation, lawyers focus on the word "order" because it suggests how various levels of government will relate to one another at a formal level. In the context of arms control, we usually think of treaties as the contract between signatory governments embodying this new order. Thus, although treaties are not technically necessary to either verification technology or even to arms control, it is useful to understand how an arms control treaty would fit into the existing national order of the Constitution, federal statutes, and state and local laws.

1.1 CONSTITUTIONAL SUPREMACY OVER TREATIES

The most important thing to understand about the implementation of arms control treaties in the United States is that they must comply with the United States Constitution in every respect. Once ratified, treaties are the law of the land, but treaties that violate constitutional rights cannot be enforced to the extent they violate those rights. Thus, use of verification technologies in a fashion that violates the Constitution is no more legal because it is necessary to comply with an arms control treaty.

1.2 FEDERAL SUPREMACY OVER STATES

Treaties are regarded by the Supreme Court as equivalent to federal statutes. This means that they are superior to all state and local laws, including state constitutions; conflicts between treaties and state or local laws are resolved in favor of treaties. Therefore, verification activities that are necessary to comply with an arms control treaty would take precedence over a state or local law that prohibits these activities, even if the state law is the state constitution itself.

1.3 "LATER IN TIME" DECIDES CONFLICTS BETWEEN FEDERAL LAWS

A more subtle problem is presented by conflicts between treaties and federal statutes. Since treaties are essentially equivalent to federal statutes, conflicts between those resolved the same way as are conflicts between two federal statutes. Observing, as they must, the myth that Congress knows what it is doing when it enacts seemingly contradictory laws, courts will strive mightily to interpret the words of such laws so that they are consistent with each other, regardless of their plain meaning. However, if a contradiction is so glaring that it cannot be papered over, courts will infer that the more recent of the two laws was intended by Congress to amend implicitly the earlier one. This may be particularly important for an arms control treaty that otherwise could run afoul of many previously enacted federal health, safety, or environmental statutes.

2 VERIFICATION AND THE CONSTITUTIONAL RIGHT TO PRIVACY

The special concern of the Fourth Amendment[1] to the United States Constitution is that government authority respect a person's "reasonable expectations of privacy."[2] The Supreme Court has adopted the general rule that a search warrant[3] is a necessary

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[1]The Fourth Amendment reads:

> The right of the people to be secure in their persons, house, papers and effects, against unreasonable searches and seizures, shall not be violated, and no Warrants shall issue, but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized.

U.S. CONST. amend. IV.

[2]Katz v. United States, 389 U.S. 347, 360-62 (1967) (Harlan, J., concurring).

[3]A search warrant is defined as:

> [a]n order in writing, issued by a justice or other magistrate, in the name of the state, directed to a sheriff, constable, or other officer, authorizing him to search for and seize any property that constitutes evidence of the commission of a crime, contraband, the fruits of crime, or things otherwise criminally possessed; or property designed or intended for use or which is or has been used as the means of committing a crime.

BLACK'S LAW DICTIONARY 1350 (6TH ed. 1991).

prerequisite to a constitutionally valid inspection.[4] The justification for this rule is that a magistrate interposes a neutral review process between the government agency seeking the inspection and its subject.[5] Central to this review process is the requirement that the government prove to the magistrate that it has "probable cause" to believe that the proposed search will discover evidence of a violation.[6]

The requirement for search warrants based on probable cause can be a problem for arms control verification activities in the United States. Assuming that the draft Chemical Weapons Convention[7] (CWC) is indicative of how this and other arms control treaties will be verified, search warrants may not always be obtainable before private property must be examined by international inspectors to verify continued American compliance. Thus, the potential exists for treaties like the CWC to violate the Fourth Amendment.

Fortunately, development of constitutionally uninstrusive verification technologies may offer a way in some instances to avoid a self-defeating choice between complying with the Fourth Amendment and complying with the verification obligations in an arms control treaty. The definition of what constitutes a "search" under the Fourth Amendment offers a kind of loophole through which some verification technologies may pass constitutional muster. Thus, development of instruments whose use passes these tests is a desirable goal, although any technical limitations are beyond the scope of this conference paper.

2.1 DEFINITION OF SEARCH

While warrants are generally required for searches, not all government inspections are "searches." For example, a person has no reasonable expectation of privacy in objects that are in "plain view," because these are visible for anyone to see.[8] Accordingly,

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[4]Camara v. Municipal Court 387 U.S. 523, 528-29 (1967).

[5]United States v. Chadwick, 433 U.S. 1, 9 (1977).

[6]"Probable cause," although defying simple definition, has been characterized as "a fair probability that contraband or evidence of a crime will be found in a particular place." Illinois v. Gates, 462 U.S. 213 (1983).

[7]This conference paper is based on the 20 January 1992 version of the Draft Convention, also referred to as the "rolling text," United Nations Conference on Disarmament: *Report of the Ad Hoc Committee on Chemical Weapons to the Conference on Disarmament on its Work during the Period 30 September 1991 to 20 January 1992*, U.N. Doc, CD/1116 [hereinafter CWC or Draft Convention]. A key part of the rolling text for this analysis is the Addendum to App. I, Protocol on Inspection Procedures [hereinafter Protocol on Inspection Procedures], which specifies the details of the CWC on-site inspection scheme.

[8]*See* Marshalls v. Barlow's Inc., 436 U.S. 307, 315 (1978).

inspectors are not conducting "searches" when they sense (see, hear or smell) what is detectable by anyone nearby.[9]

2.1.1 Detection of Contraband

The Supreme Court decision in *United States v. Place*[10] illustrates how the definition of a search may be adapted to permit use of verification technologies that do not require search warrants instead of relying exclusively on people to conduct searches in a fashion that might trigger the warrant requirement. In *Place*, the defendant was at an airport about to board an airplane when agents of the U.S. Drug Enforcement Administration (DEA), prompted by Place's suspicious behavior, used a trained dog to sniff his previously checked baggage for illegal drugs. The dog indicated that such contraband was present, and Place was arrested and convicted for cocaine possession. On appeal, Place challenged the use of the dog, claiming that this was a search in violation of the Fourth Amendment because it had not been preceded by a search warrant issued by a judge. The Supreme Court disagreed, concluding that use of the dog "did not constitute a 'search' within the meaning of the Fourth Amendment"[11] in part because this technique "does not expose noncontraband items that otherwise would remain hidden from public view."[12]

In *United States v. Jacobsen*,[13] the Supreme Court extended its reasoning in *Place* to include chemical tests. In this case, DEA agents used a cocaine field test kit on a package that defendant Jacobsen had mailed, but which had broken open en route and had aroused the suspicion of an express company employee who noticed it. Jacobsen challenged use of the test results in his trail, alleging that the test was an unconstitutional warrantless search. This time, the Supreme Court ruled that:

> [a] chemical test that merely discloses whether or not a particular substance is cocaine does not compromise any legitimate interest in privacy. . . . Congress has decided - and there is no question about its power to do so - to treat the interest in "privately" possessing cocaine as illegitimate; thus government conduct that can reveal whether a substance is cocaine, and no other arguably "private" fact, compromises no legitimate privacy interest.[14]

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[9] Air Pollution Variance Bd. v. Western Alfalfa, 416 U.S. 861 (1973).

[10] 462 U.S. 696 (1983).

[11] Id. at 707.

[12] *Id.*

[13] 466 U.S. 109 (1984).

[14] *Id.* at 123.

Thus, if a government agent legally gains access to an item,[15] it can be tested without a search warrant for contraband provided that the test reveals only the presence or absence of the controlled substance, and no other private information.[16]

2.1.2 LOCATION OF VERIFICATION ACTIVITIES

The locations where verification instruments are used presents a distinct problem from their actual use.[17] "The Supreme Court has recognized that one's expectation of privacy and his whereabouts are closely linked."[18] Operation of detection instruments in areas where one has "resonable expectation of privacy,: even a test identical to what the Supreme Court in *Jacobsen* upheld, may itself be illegal in the absence of a search warrant. In contrast, sensing of activities in areas with reduced privacy protection, even private property, may be constitutionally acceptable. Thus, it is necessary to understand where such instruments may be used in order to reduce the chance of triggering the requirements of the Fourth Amendment when they are used.

Some areas - most importantly homes - are protected to a greater extent by the Fourth Amendment from government surveillance. In *United States v. Thomas*[19], the Court weighed whether detection of illegal drugs inside defendant Wheelings' apartment by a dog who sniffed them from the adjacent public hallway was an unconstitutional search. Distinguishing the search in *Place*, which occurred at an airport, the Court pointed out that: a practice that is not intrusive in a public airport may be intrusive when employed at a person's home. Although using a dog sniff for narcotics may be discriminating and unoffensive relative to other detection methods, and will disclose only the presence or absence of narcotics, it remains a way of detecting the contents of a private, enclosed space. . . . Here the defendant had a legitimate expectation that the contents of his closed apartment would remain private, that they could not be "sensed" from outside

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[15]It is important to note that forced biomedical testing of humans in order to verify compliance with an arms control treaty is an entirely different matter outside the scope of the conference paper. *See* E. Tanzman & B. Kellman, *Harmonizing the Chemical Weapons Convention with the United States Constitution* 53-57 (DNA TR-91-216 1992).

[16]"*Place* and *Jacobsen* stand for the proposition that a possessor of contraband can maintain no legitimate expectation that its presence will not be revealed. Stated otherwise, governmental conduct that can reveal nothing about noncontraband items interferes with no legitimate privacy expectation." United States v. Colyer, 878 F.2d 469, 474 (D.C. Cir. 1989) (citation omitted).

[17]"A 'search' occurs when an expectation of privacy that society is prepared to consider reasonable is infringed." United States v. Jacobsen, 466 U.S. 109, 113 (1984) (footnote omitted).

[18]United States v. Colyer, 878 F.2d 469, 475 (D.C. Cir. 1989).

[19]757 F.2d 1359 (2d Cir. 1985).

his door. Use of the trained dog impermissibly intruded on that legitimate expectation. . . .Because of defendant Wheelings' heightened expectation of privacy inside his dwelling, the canine sniff at his door constituted a search.[20]

In contrast, the Fourth Amendment affords less protection from government searches of private commercial property. "[T]he expectation of privacy that the owner of commercial property enjoys in such property differs significantly from the sanctity accorded an individual's home. . .[21] Thus, use of detection instruments to observe commercial enterprises is more likely to win court approval than to observe activities in homes,[22] especially where the subject of an arms control inspection is part of a "pervasively regulated industry" that is not entitled to the protections provided by search warrants at all.[23]

At the opposite end of the spectrum from homes are government property and public places. "The national government itself has no constitutional rights, and it may agree to grant foreign inspectors access to government facilities, records, and weapons."[24] And although there are times when activities in public places are considered to be private,[25] "[w]hat is observable by the public is observable without a warrant, by the Government inspector as well."[26]

2.2 LESSONS FOR VERIFICATION TECHNOLOGY DEVELOPMENT

These aspects of the Fourth Amendment can help guide the development of verification technology. Instruments to detect potential noncompliance with an arms control treaty can be designed to emulate those upheld in *Place* and *Jacobsen*. They can be planned

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[20] *Id.* at 1367.

[21] Donovon v. Dewey, 452 U.S. 594, 598-99 (1981) (citation omitted).

[22] *See* Dow Chemical Co. v. United States, 476 U.S. 227, 238 (1986).

[23] E. Tanzman & B. Kellman, Harmonizing the Chemical Weapons Convention with the United States Constitution 21-30 (DNA TR-91-216 1992).

[24] Koplow, *Arms Control Inspection: Constitutional Restrictions on Treaty Verification in United States*, 63 N.Y.U.L. REV. 229, 291 (1988) *citing* L. HENKIN, FOREIGN AFFAIRS AND THE CONSTITUTION 390 (1972); D. ARONOWITZ, LEGAL ASPECTS OF ARMS CONTROL VERIFICATION IN THE UNITED STATES 103 (1965); L. DUNN & A. GORDON, ON-SITE INSPECTION FOR ARMS CONTROL VERIFICATION: PITFALLS AND PROMISE 40 (Center for National Security Negotiations Paper, vol. 1, no. 2, 1989). *See* Davis v. United States, 328 U.S. 582 (1946) (warrantless search of defendant's gasoline station office for gasoline rationing coupons, which were being used in a black market scheme, upheld in part because the coupons remained the property of the federal government even while in the possession of gasoline dealers).

[25] TO BE ADDED

[26] Marshalls v. Barlow's, Inc., 436 U.S. 307, 315 (1978).

for use in locations where they are permissible.

2.2.1 Instrument Selectivity

The key to designing detection instruments that will avoid triggering the privacy protections of the Fourth Amendment is to make them highly selective for evidence of a treaty violation. "Selectivity" can be thought of as the ability of an instrument to receive some signals as input while rejecting others.[27] It is this characteristic that the Supreme Court endorsed in *Place* and Jacobsen when it noted that the detectors in those cases only could reveal the presence of contraband. Thus, selective instruments run less of a risk causing a confrontation between an arms control treaty and the Fourth Amendment.

2.2.2 Locations Planned for Instrumentation

Instruments to verify arms control treaty compliance may not all be suitable for the same locations if search warrants are unavailable. Without a search warrant, it is questionable whether courts would permit use of even very selective instruments to detect evidence of treaty violations in private homes. Instrumentation of commercial property is more likely to be approved, especially if the firm is pervasively regulated.[28] Finally, instruments used in government facilities or in public places will usually not pose Fourth Amendment problems at all because these locations are not generally protected by the Fourth Amendment.[29]

3 ENVIRONMENTAL LAW CONSTRAINTS ON VERIFICATION TECHNOLOGY

3.1 ENVIRONMENTAL PROTECTION AND THE CWC

Under Article VI of the draft CWC, facilities which produce, process or consume toxic chemicals or precursors listed in Schedule 1, 2A, and 2B shall be subject to international monitoring. Each State Party also has the right to request an on-site challenge inspection of any facility or location for the sole purpose of clarifying and resolving any questions concerning compliance with the provisions of the Convention and to have this inspection conducted anywhere without delay. This monitoring may include sampling. Such sampling may result in planned release of hazardous

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[27]More precisely, selectivity is "the ability for a radio receiver to separate a desired radio frequency from other signal frequencies some of which may differ only slightly from the desired value." McGraw-Hill Encyclopedia of Science & Technology, *Selectivity* 243 (6th ed. 1987).

[28]See Tanzman & Kellman, *Harmonizing the Chemical Weapons Convention with the United States Constitution* 25-30 (DNA TR-91-216 1992).

[29]However, it should be noted that government employees themselves may have privacy rights in certain areas of government facilities. O'Connor v. Ortega, 107 S. Ct. 1492 (1987); need US cite?

substances as air or effluent emissions, or the creation of hazardous wastes which will require disposal.

Each State party, during the implementation of its obligations under this Convention, shall assign the highest priority to ensuring the safety of people and to protecting the environment, and shall cooperate as appropriate with other States Parties in this regard. Article VII, National Implementation Measures, General Undertakings). Therefore, this part of the paper will survey the United States environmental laws and regulations which may limit or condition the use of verification equipment the handling of samples and the disposal of wastes created during sampling analysis.

Most chemical, pesticide and pharmaceutical manufacturers and processors in the United States are heavily regulated concerning the storage, use and disposal of the chemicals used in their processes. Usually this regulation takes the form of reporting, however, these facilities most likely will also hold certain permits or approvals concerning the release of pollutants to the environment. Releases of hazardous substances/waste into the environment and the operation of laboratory, storage, treatment, or disposal faciiities may require permitting or reporting under the provisions of the Clean Air Act, as amended, the Resource Conservation and Recovery Act, the Clean Water Act and associated regulations, to what extent, if any, is not clear. Whether and how they will apply presents many of the conflicts highlighted in section 1. The resolution of these conflicts turn on who does the inspections and takes the samples (e.g. international body or foreign sovereign), the nature of the inspections and the parties' respective obligations under the treaty as ratified. While many legal issues have yet to be resolved, the full application of environmental laws creates numerous complications which will be discussed in this section.

3.1.1.1 Declared Schedule 1, 2, and 3 Facilities

For the production of chemicals on Schedule 1 for research, medical, pharmaceutical or protective purposes, the inspection team must verify that the quantities of Schedule 1 chemicals produced are correctly declared. This may require sampling for identification of declared Schedule 1 chemicals and of other chemicals present in the facility. In addition, the team must determine the aggregate amount of declared Schedule 1 chemicals produced.

For facilities which have declared they produce, process or consume more than 10 tons of chemicals listed in Schedule 2, the team must verify the identity and amount of declared chemicals present at the facility. The team must also verify that there has been no diversion of Schedule 2 chemicals for purposes prohibited under the Convention.

The areas of a Schedule 2 facility to be inspected may include:

(i) Areas where feed chemicals (reactants) are delivered and/or stored;

(ii) Areas where manipulative processes are performed upon the reactants prior to addition to the reaction vessel;

(iii) Feed lines appropriate from subparagraph (i) and/or subparagraph (ii) to the reaction vessel together with any associated valves, flow meters, etc.;

(iv) The external aspect of the reaction vessel and its ancillary equipment.

(v) Lines from the reaction vessel leading to long- or short-term storage or for further processing of a designated chemical;

(vi) Control equipment associated with any of the items under subparagraphs (i) to (v);

(vii) Equipment and areas for waste and effluent handling; or

(viii) Equipment and areas for disposition of off-specification chemicals.

During an inspection of a Schedule 1 or 2 facility, at the request of the inspection team in the presence of inspectors, representatives of the inspected State Party or of the inspected facility shall take samples at any of the above areas. If agreed in advance, the inspection team may take samples themselves. Where possible, the analysis of samples shall be performed on-site. The inspection team shall have the right to perform on-site analysis of samples using approved equipment brought by them. At the request of the inspection team, the inspected State Party shall, in accordance with agreed procedures provide assistance for the analysis of samples on-site. Alternatively, the inspection team may request that appropriate analysis on-site be performed in their presence. The inspected State Party has the right to retain portions of all samples taken or take duplicate samples and be present when samples are analyzed on-site. (Protocol on Inspection Procedures, Appendix 1, Addendum, Part I, VI(E)).

The inspection team shall, if they deem it necessary, transfer samples for analysis off-site at laboratories designated by the Organization. When off-site analysis is to be performed, samples shall be analyzed in at least two designated laboratories, and the samples will be accounted for by the Secretariat and unused samples or portions thereof shall be returned to the Secretariat. Hazardous samples shall be transported in accordance with relevant regulations (Protocol on Inspection Procedures, Appendix I, Addendum, Part I, III(2)(iv)), which in the United States, is the Department of Transportation packaging and labelling regulations (49 CFR Parts 172 and 173).

Equipment necessary to fulfill the inspection requirements will be approved by the Secretariat. The equipment shall be in the custody of the Secretariat and be designated, calibrated and approved by the Secretariat. In establishing the list of approved equipment and these regulations, the Technical Secretariat should ensure that safety considerations for all the types of facilities at which such equipment is likely to be used, are taken fully into account. The Technical Secretariat shall select that equipment which is specifically designed for the specific kind of inspection required.

At this stage, what types of sampling equipment will be listed by the Technical Secreatariat is unknown, therefore, it is impossible to speculate what, if any, emissions or wastes will be created by the sampling activities. There may be cases where the inspection teams finds it necessary to use equipment available on site not belonging to the Secretariat and requests the inspected State Party to enable the team to use such equipment. (Protocol on Inspection Procedures, Appendix I, Addendum, Part I, IV(D)). Such facility-supplied equipment should comply with all environmental, health and safety regulations governing the operation of the facility.

Some common analytical instrumentation items which may be considered are:

- Gas Chromatography (GC)
- Liquid chromatography (LC)
- Ultraviolet analysis (UV)
- Total organic carbon (TOC)
- Differential scanning calorimetry (DSC)
- High Performance Liquid Chromatograph (HPCL)
- Supercritical Fluid Chromatograph (SFC)
- Capillary Zone Electrophoresis Systems (CZE)
- Mass Spectrometers (MS)
- Infrared Spectrophotometer (IR)
- Nuclear Magnetic Resonance Systems (NMR)
- Process Analysis Instruments (PAI)

Sampling equipment could include pumps, flow control equipment, syringe, or automatic composite samplers. To physically monitor the production or consumption quantity of chemicals at a facility processes may require pH, pressure, temperature, viscosity and volume indicators. Equipment for identification could include GC/MS, GC/IR, near IR, neutron-inducted gamma emission, ultrasonic, calorimetric and conductivity instruments. For toxic chemicals, non-extraction sampling would be preferred.

For Schedule 2 facilities (and for chemical weapons storage and production facilities(Annex to Article III, Part IV(B) and Annex to Article V, Part IV(B)), where applicable, the Secretariat shall have the right to install and use continuous monitoring instruments and systems and seals in conformity with the relevant provisions in the Convention (Protocol on Inspection Procedures, Appendix I, Addendum, Part II, III(A)). Continuous monitoring systems consisting of, *inter alia*, sensors, ancillary equipment and transmission systems shall be specified in the facility agreements. They shall incorporate, inter alia, tamper-indicating and tamper-resistant devices as well as data protection and data authentication features. The agreed types of these instruments shall be specified in the Model Agreement. The Technical Secretariat shall have the right to carry out necessary engineering surveys, construction, emplacement, maintenance, repair, replacement and removal of continuous monitoring instruments and systems and seals. The inspected State Party shall provide the necessary preparation and support for the establishment of continuous monitoring instruments and systems.

Many chemical manufacturers are already installing on-line analytical instruments to perform composition-analysis for good business reasons. These include autosamplers or autoinjection analytical instrumentation with separate sampling lines. Choosing an on-line sampler depends on whether the sample will be disposed of as waste or recycled, the chemical properties of the sample, i.e., corrosivity, necessary safety equipment, as well as all other process needs. It is possible when toxic or corrosive vapors are present to use diaphragms and "pancake" flanged designs. For business reasons it is desirable to have analyzers that do not require elaborate extraction sampling systems, such as for pH, conductivity and resistivity. However, if it is necessary to measure color, moisture, spectrographic properties (as with an ultraviolet or infrared analyzer) or the presence of particular ions, the analyzer is more likely to require a extraction sampling system with some stream conditioning, such as filtration.

At Schedule 3 facilities, the inspection is to verify that the activities at those plants are consistent with obligations under the Convention, including that there are no non-declared chemicals present at the plant. However, there is no provision for sampling in these facilities. Therefore, there should be no emissions, effluents or wastes disposal problems.

3.1.1.2 Challenge Inspections

Each State Party has the right to request an on-site challenge inspection of any facility or location for the sole purpose of clarifying and resolving any questions concerning compliance with the provisions of the Convention and to have this inspection conducted anywhere without delay. Subject to safety and other precautions, as necessary, the inspection team shall itself have the right to take any air, soil, wipe or effluent samples from the inspection site. Unlike the sampling provisions for chemical weapons storage and production facilities and for Schedule 1 and 2 facilities, the samples are specifically limited to air, soil, wipe or effluent. Therefore, it could be interpreted such challenge inspection sampling would not include extracting samples from process tanks, lines, storage areas or control equipment, but only sampling of ambient air, uncontained soil, outside surface residue and outfall effluent streams.

Therefore, it is less likely that such a sampling procedure would involve an air emissions, however, it could result in sampling residual or analysis residue which would have to be stored, treated or disposed of as hazardous waste or wastewater. However, once a distrust of the facility is stated, the use of public reports, on-site analytical test reports, instrument readings and calibrations may become suspect. At that point, the choice of portable analysis equipment will become more important, to ensure the equipment does not emit hazardous air pollutants or uncontained effluent streams while the analysis is being performed.

3.1.2 Current Potential Permitting Requirements

During the actual sampling extraction process, where air emissions are likely to occur, the provisions of Clean Air Act must be considered. If a facility currently is a permitted facility under the CAA, the permit may need to be altered to accommodate the emission, or because the addition of sampling ports or equipment may be considered a modification for which reapplication is necessary. After sampling and analysis have been completed, there is the potential to create hazardous waste (liquid or solid) and the provisions of RCRA and the CWA must be considered. Again, if a facility currently holds a hazardous waste permit or a water discharge permit, such permits may need to be altered to accommodate the storage, treatment or disposal of hazardous waste or the discharge of hazardous effluent into a water system. Also, if the facility does not currently hold a permit for any of the actions required for the disposal of such waste, one must be obtained.

Under RCRA, certain hazardous wastes can be disposed of as wastewater mixtures, provided they are in compliance with the Clean Water Act effluent limitations or pre-treatment regulations. Therefore, as you can see, these regulations must be reviewed in conjunction when considering various sampling and subsequent treatment or disposal alternatives.

3.1.2.1 Clean Air Act

Under the Clean Air Act, each State has primary responsibility for the implementation, maintenance and enforcement of primary ambient air quality standards within such State. The State issues a permit for each major stationary source of emissions prescribing the allowable emission limits, conditions of operations and required pollution control equipment necessary to maintain and achieve the national ambient air quality for the region and to prevent significant deterioration of air quality or visibility. Permits for major sources of air pollutants normally concern emissions of particulates, NOX or SO_2, but not air toxics.

3.1.2.1.1 National Emission Standards for Hazardous Air Pollutants (NESHAPS)

Under the NESHAPs (40 CFR 61), no owner or operator of a regulated source of hazardous air pollutants may operate in violation of published standards. Any new construction or modification of existing facilities requires approval of the EPA or an authorized State agency, finding the facility will be in conformance with the regulations. NESHAPS, however, generally regulates only very specific emissions from particular types of facilities, i.e., benzene emissions from benzene storage vessels, inorganic arsenic emissions from arsenic trioxide and metallic arsenic production facilities, etc.

Currently, the only section of NESHAPS which might apply to Schedule 1 or 2 facilities is Subpart V - National Emission Standards for Equipment Leaks (Fugitive Emission Sources). This Subpart applies to equipment that is intended to operate in volatile hazardous air pollutant service, including pumps, compressors, pressure relief devices, sampling connection systems, open-ended valves or lines, valves, flanges and other connectors, product accumulator vessels, and control devices or systems required by such service. The provision specifically exempt in situ sampling systems, i.e., non-extractive samplers or on-line samplers, so if in-line sampling or continuous monitoring equipment can be chosen, this Subpart of NESHAPS would not apply.

If an in situ sampling procedure cannot be used or has not been developed for a particular process or chemical, Subpart V provisions specifically apply to sampling connection systems which may be part of a continuous emission monitoring instrument or extraction sampling ports required under CWC verification. It also covers closed-vent systems, i.e., system not open to atmosphere (composed of piping, connection and if necessary, flow-inducing devices that transport gas or vapor from a piece of equipment to a control device. A control device may be enclosed combustion device, vapor recovery system or flare.

For instance, under these regulations, sampling connecting systems must be equipped with a closed-purge system or closed vent system which returns the purged process fluid directly to the process line with zero pollutant emissions to atmosphere or collects and recycles the purged process fluid with zero pollutant emissions to atmosphere or is designed and operated to capture and transport all the purged process fluid to a control device which is also designed for and operated with no detectable emissions, as indicated by an instrument reading of less than 500 ppm above background and by visual inspections (61.242-11(f)(1)).

Compliance is determined by a review of records, review of performance test results and inspection. Each owner or operator must report semiannually the performance tests and monitoring of the process unit, associated valves, pumps, compressors, sampling connections, and any revisions to items which have occurred since the last report. If a unit was altered or the process changed to allow for CWC sampling, the report would have to reflect these changes and it would have to be shown that the devices continue to be operated with no emissions to the atmosphere or are exempt from regulation.

Under current NESHAPS regulations, any modification to a regulated facility, including any physical or operational change which results in an increase in the rate of emissions to the atmosphere of a hazardous pollutant or emission of a new pollutant to which a standard applies, would require application by the facility for approval. Therefore, a declared facility which is also a regulated facility under NESHAPS would have to show sampling under the CWC is not a modification which result in an increase in emissions into the atmosphere, or an application for approval of the modification would be necessary. Therefore, again, it would be better to chose or develop an in situ sampling system, if possible.

3.1.2.1.2 Clean Air Act Amendments of 1990

The Clean Air Act Amendments of 1990 amended Section 112 of the Clean Air Act to require the EPA to promulgate regulations establishing emission standards for 188 hazardous air pollutants listed for regulation. Currently, no Schedule 1 or 2 chemicals are specifically named on the list, however, arsenic trichloride could be included in the general category of arsenic compounds (inorganic including arsine).

The emission standards promulgated will be applicable to new or existing major sources of hazardous air pollutants. These standards will require the maximum degree of reduction in emissions of the hazardous air pollutants (including a prohibition on such emissions, where achievable). These standards will be in the form of maximum achievable control technologies rather than emission limits. The EPA is to take into consideration the cost of achieving such emission reduction, and any non-air quality health and environmental impacts and energy requirements, in determining what is achievable for new or existing sources, through application of measures, processes, methods, systems or techniques including, but not limited to measures which (a) reduce the volume of, or eliminate emissions of, such pollutants through process changes, substitution of materials or other modifications; (b) enclose systems or processes to eliminate emissions, (c) collect, capture or treat such pollutants when released from a process, stack, storage or fugitive emission point, (d) are design, equipment, work practice or operational standards (including requirements for operator training or certification) or (e) a combination of the above.

The list of all categories and subcategories of major sources and area sources to be regulated was to be published within 12 months after the enactment of the Clean Air Act Amendments (October 26, 1990). The emission standard regulations were to be issued for each such category and subcategory as expeditiously as practicable over a ten-year period starting October 26, 1990. On June 17, 1991, EPA announced a preliminary draft list of its source categories (56 Fed.Reg. 28548 (June 21, 1991)). However, EPA has not issued a final list, and thus has missed its deadline. Consequently, EPA has not issued any emissions standards.

It is anticipated, however, these new regulations will cover toxic air pollution emissions from facilities which produce, process and consume toxic chemicals which are not currently regulated under current Clean Air Act permits or NESHAPS regulations. The chemical industry is well aware that air toxic emissions will be curtailed under the new emission standards. Anticipated maximum achievable control technology (MACT) standards will require more controls to be installed on more sources and at more facilities than under current EPA regulations.

Existing sources must meet the MACT standards within three years of their issuance. However, companies can sign up to make commitments to lower toxic air emissions by 90% (or 95% if the pollutant is also a particulate) before emission standards are proposed and, thereby, get a six-year grace period on meeting MACT standards. If the source is granted a compliance extension, an alternative emission limitation will be established by permit to ensure continued achievement of the commitment. In addition, an existing source which has installed the best available control technology ("BACT") or the lowest achievable emission rate ("LAER") prior to the promulgation of a MACT standard gets a five-year extension from meeting MACT standards. Therefore, if a company has elected to meet the 90% reduction commitments or installed BACT or LAER technology to delay the time for installing the potentially more stringent MACT, it is very important that the installation of any continuous monitoring equipment or sampling equipment is in compliance with these technologies, or the alternate emissions permit may be violated and the applicable MACT standard would be triggered.

If a major source does not get an extension, a permit will be issued establishing the MACT applicable to that source for the hazardous air pollution emitted from that facility. No person may modify a major source of hazardous air pollutants unless the EPA or the state determines that the modification will also meet the maximum achievable control technology emission limitation. Therefore, once a facility has obtained its permit, a change in operations which increases emissions by more than a de minimis amount or results in more that de minimis emissions of a different hazardous air pollutant due to sampling could require an amendment to the permit. Companies hope for enough flexibility to be able to make process changes without reapplying. EPA's original permit rule, proposed May 10, 1991, allowed for minor permit amendments without public review. However, in January, 1992, EPA revised the proposal to require companies to have a 21-day public review period and a 45-day EPA review period. After 45 days the company could make the changes under an "interim permit". Therefore, the definition of "de minimis" has become very important. In choosing sampling procedures and equipment, it will be important to determine what is a de minimis emission for the facility concerned.

Under the Area Source Program (Section 112(k)), emissions of hazardous air pollutants from area sources, defined as sources which do not emit sufficient amounts of pollutants to be major sources, may come under regulation. The Congress found that these area sources may individually, or in the aggregate, present significant risks to public health in urban areas. Considering the large number of persons exposed and the risks of carcinogenic and other adverse health effects hazardous air pollutants, ambient concentrations characteristic of large urban areas should be reduced to levels substantially below those currently experience. It is the purpose of this program to achieve a substantial reduction in emissions of thirty most dangerous hazardous air pollutants from area sources and an equivalent reduction in the public health risks associated with such sources including a reduction of not less than 75 percent in the incidence of cancer attributable to emissions from such sources. The program includes consultation with the state and local air pollution control officials and the EPA to conduct a program of research with respect to sources of hazardous air pollutants in urban areas and shall include ambient monitoring, analysis of characterize the sources of such pollutants with a focus on area sources and the contribution that such sources make to public health risks and consideration of atmospheric transformation and other factors which can elevate public health risks from such pollutants.

California, for instances, has recently issued legislative findings on planned and unplanned releases of toxic chemicals into the atmosphere (Cal. Health and Safety Code, Division 26 - Air Resources, Part 6 - Air Toxics "Hot Spots" Information and Assessment, Chapter 1 - Legislative Findings and Definitions). These findings state it was documented that nearly every large chemical company surveyed by the Congressional Research Service, routinely releases into the surrounding air significant levels of substances proven to be or potentially hazardous to public health. California fears these releases may create localized concentrations or air toxic "hot spots" where emissions from specific sources may expose individuals and population groups elevated risks of adverse health effects, including, but not limited to, cancer and contribute to the cumulative health risks of emissions from other sources in the area. The state intends to implement a long-term program to identify, assess and control ambient levels of hazardous air pollutants.

Although currently, no Schedule 1 or 2 chemicals are on the list of hazardous air pollutants, the EPA has the power to add pollutants which present, or may present, through inhalation or other routes known to be, or may be reasonably be anticipated to be carcinogenic, mutagenic, teratogenic, neurotoxic, which cause reproductive dysfunction or which are acutely or chronically toxic) or adverse environmental effects whether through ambient concentrations, bioaccumulation, deposition or otherwise. Therefore, if a chemical weapon or precursor chemical is later added to the list, sampling procedures may have to be altered to conform to new emissions standards.

3.1.2.1.3 State Air Toxics Programs

Currently states may regulate air toxics separately from NESHAPS and the air toxics provisions of the Clean Air Act Amendments of 1990. Such state air toxics programs usually express their standards as fractions of occupational exposure standards such as OSHA permissible exposure levels or American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values. Most state air toxics programs require facilities to install particular types of control technologies to reduce air toxics emissions. Therefore, a state toxics program may already require a facility to meet certain control technologies, and modification could trigger reassessment. Nothing in the Clean Air Act Amendments of 1990 restricts state air toxics programs from imposing more stringent requirements than the federal program, so existing state requirements may continue even after the EPA issues its standards. For states without programs, or with less stringent programs, the new MACT standards would become applicable.

3.1.2.2 Clean Water Act

The objective of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the nation's waters. This is achieved through the control of discharges of pollutants to all surface waters, and in some states groundwater. The CWA prohibits the discharge of any pollutant into the waters of the State. The definition of a pollutant includes any munitions, chemical wastes and industrial waste discharged into water.

There are three categories of pollutants: priority or toxic pollutants; conventional pollutants, such as biochemical oxygen demanding (BOD), total suspended soils (TSS), fecal coliform, oil and grease and pH; and nonconventional pollutants, which is any pollutant that is not conventional or priority, i.e., ammonia nitrogen, chemical oxygen demand (COD), total organic carbon, total solids and nonpriority toxic pollutants. Currently, none of the Schedule 1 or 2 chemicals are listed as toxic pollutants under Section 307 of the Act.

States have primary enforcement responsibilities, including permitting under the National Pollutant Discharge Elimination System (NPDES) program. NPDES permits contain applicable effluent standards, monitoring requirements and standard and special conditions for discharge. The state water quality standards are usually based on Federal ambient water quality criteria, but may be more stringent. Effluent standards for the permit are developed based on a whole-effluent approach and/or a chemical-specific approach. Therefore, the discharge of a chemical sample or sample analysis residue may be a part of a facility's complex wastewater stream and must meet the whole-effluent standards under the permit or may be required to meet a chemical-specific standard.

Not all facilities may need a NPDES permit, but instead may discharge its wastewater to a publicly owned treatment works (POTW). In this case, the facility must meet certain pre-treatment standards. Generally, pre-treatment standards require a discharge not pass through (i.e., is not susceptible to treatment by the POTW), or interfere with the POTW operations (i.e., inhibit or destroy the operations, contaminated sludge, or endanger the health of POTW workers). For many industries, EPA has promulgated national categorical pre-treatment standards for toxic pollutants. However, such standards do not cover all industrial categories or regulate all of the pollutants discharged from industrial facilities. These standards are enforced through the pre-treatment plans required to be filed by the POTW with the State water pollution control agency and enforced by the POTW, itself. A POTW may enforce local prohibitions on wastes with objectionable color, noxious or malodorous liquids, wastes that may volatilize in the POTW, radioactive wastes, and other types of wastes that are incompatible with POTW operations.

Before allowing a discharge of industrial wastewater into its system, the POTW enters into an agreement with the industrial discharger setting out the limits on discharges which will be accepted. The POTW may monitor the industrial facilities discharge points to confirm the wastewater is in conformance with the pre-treatment standards set out in such agreement. If a facility anticipates a large discharge, it may be required under its agreement to inform the POTW of the time of the discharge to allow the POTW to coordinate its treatment operations. Therefore, if an inspection could result in a large quantity or unusual combination of sample waste, before allowing such discharge, the declared facility would have to determine if the amount and composition of the discharge is within the agreed pre-treatment limits. If not, the pre-treatment agreement must be amended, or the waste must be disposed of another way.

3.1.2.3 Resource Conservation and Recovery Act (RCRA)

RCRA governs the storage, treatment and disposal of hazardous waste. Once samples have been taken, analyzed and reported, they may become hazardous waste if there is no possibility that the sample residual or analysis residue can be recycled back into the process. RCRA is implemented and enforced by each state under an EPA-approved implementation plan. The state regulations usually mirror the federal regulations, however, a state may adopt more stringent requirements or expand the list or hazardous wastes to include additional chemicals or mixtures.

Normally, any commerical chemical product, or manufacturing chemical intermediate as listed, when discarded or intended to be discarded are hazardous wastes (261.33(a)). Currently, no Schedule 1 or 2 chemicals are listed under 261.33.[30] however, as stated above each state may list hazardous wastes in addition to those included in the federal regulations. Under the federal regulations, however, a discarded commerical chemical product or chemical intermediate listed in 261.33, which arises from de minimis losses of these materials from manufacturing operations in which these materials are used as raw materials or are produced in the manufacturing process, specifically including sample purgings are not hazardous wastes, if they are mixed with wastewater which is discharged in compliance with the Clean Water Act (261.3(2)(iv)(D). Also, wastewater containing toxic wastes listed in Subpart D are not hazardous wastes if they result from laboratory operations. Provided, however, the annualized average flow of laboratory wastewater does not exceed one percent of total wastewater flow into OR the combined annualized average concentration does not exceed one part per million in the headworks of the facilities wastewater treatment or pre-treatment system. Therefore, to avoid RCRA regulations, if possible, the disposal of sample residual or analysis residue, it would be wise to ensure samples taken to not exceed an amount which would prevent disposal as a wastewater mixture.

If the wastewater exemption cannot be used or if contaminated ash, filters, containers, or other non-liquid sampling wastes are to be discarded, the waste must be handled pursuant to the governing state RCRA regulations. First, it must be determined either through analysis or process knowledge whether the waste is a hazardous waste under RCRA. This would include waste which (1) exhibit any of the characteristics of hazardous waste, identified as ignitability, reactivity, and toxicity, (2) is a listed waste, or (3) is a mixture of a hazardous waste and a solid waste which exhibits one or more of the characteristics of hazardous waste.

If the the waste is a hazardous waste, the facility will have to obtain an EPA identification number as a generator of hazardous waste. A generator must not offer the waste to transporters or to treatment, storage or disposal facilities that have not also received an EPA identification number. If the generator offers the waste to a transporter to be taken to an off-site storage, treatment or disposal facility, the generator must prepare an EPA manifest, or applicable state form. Before transporting the waste or offering it for transportation off-site, a generator must package the waste in accordance with Department of Transportation

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[30]Currently, none of the Schedule 1 or 2 chemicals are listed hazardous wastes under RCRA. Some of the chemical weapons (blister agents and phosgene) are hazardous constitutents on Appendix VIII to Part 261, however. Appendix VIII is only used by the EPA to determine whether or not to delist a hazardous waste from a specific source or for a starting point for the developing list of chemicals which an analysi must be performed in certain ground-water monitoring programs for landfills. However, Appendix VIII chemicals are not hazardous wastes.

regulations on packaging under 49 CFR parts 173, 178 and 179. Each package must be labelled according to DOT regulations. Each package must also be marked with a special designation indicating the package contains hazardous waste and improper disposal is prohibited. The transporting vehicle must bear the appropriate placard according to DOT regulations (40 CFR Part 172, Subpart F).

If the waste is to be stored at the facility for less than 90 days, the generator must place the waste in containers which comply with RCRA standards, the date upon which storage begins must be marked on the container, and the container must be marked clearly with the words "Hazardous Waste". If a facility regularly stores hazardous wastes for longer than 90 days, it will have to have a permit as a storage, treatment or disposal facility. This entails compliance with a complex set of regulations, including recordkeeping, emergency plans, closure plans and struture standards.

A generator must send its hazardous waste only to a facility which is licensed to take such waste. RCRA restricts the land disposal of certain types of wastes and specifies strict treatment standards that must be met before these wastes can be land disposed. These are the most complex regulations under RCRA. If it is determined that the sample waste is a restricted waste, and the waste does not meet the applicable treatment standards or exceeds the applicable prohibition levels, the generator must notify the treatment or storage facility in writing of the appropriate treatment standard and any applicable prohibition levels applicable to the waste, including any waste analysis data available.

3.1.2.4 OSHA

In carrying out their activities, inspectors and inspection assistants shall observe safety regulations established at the inspection site, including those for the protection of controlled environments within a facility and for personal safety. Individual protective clothing and approved equipment, duly certified, shall normally be provided by the Technical Secretariat.

Limits for air contaminants in a work place are set by OSHA. Particularly applicable to sampling activities would be the short-term exposures limits (STEL). The employer must assure that no employee is exposed to an air-borne concentration of a contaminant in excess of the limits set forth in 29 CFR 1910.1000, Table Z. None of the Schedule 1 or 2 chemicals are included in the list, however, sampling of non-declared chemicals for identification purposes may lead to exposure of a contaminant regulated under OSHA. To determine compliance with the STEL requires 15 minute employee breathing zone samples measured at operations where there is reason to believe exposures are high, such as where tanks are opened, filled, unloaded or gauged; where containers or process equipment are opened. The employer shall provide respirators and assure that they are used where required. Respirators shall be used during the time period necessary to install or implement feasible engineering and work practice controls, in work operations for which the employer establishes that compliance with STEL through the use of engineering and work practice controls is not feasible.

SESSION IV

Proliferation in a Changing World

Chairman
L. Dunn
Science Applications International Corporation

Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

Nonproliferation and Regional Security: An Integrated Approach

L. Nosenzo
Meridian Corporation

Prepared for:
Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

The Growing Dimensions of Proliferation

The primary focus of U.S. nonproliferation policy over the years has been to discourage additional countries from acquiring nuclear weapons. Our policy methods for achieving this goal include establishing regional security arrangements with nuclear security guarantees; instituting multilateral treaties and other international mechanisms; applying direct and indirect bilateral influence, including sanctions, and encouraging others to do the same; and establishing cooperative supplier efforts to deny proliferation-related exports to countries and regions of concern.

However, the wars in the Middle East, the use of chemical weapons and the spread of missile technology have highlighted the need to expand nonproliferation efforts and concerns to include chemical and biological weapons and the means to deliver these "weapons of mass destruction." In addition, there is now a clearer recognition of the fact that proliferation, whether nuclear, chemical and biological, or missile-related, is primarily fueled by regional security concerns and that dealing with proliferation requires that we also deal with the underlying security issues that provide the incentives for proliferation.

In the past, the priority given to U.S. proliferation concerns and our ability to help resolve regional security issues depended to a large extent on their implications for higher priority U.S. security objectives vis-a-vis the Soviet Union. The breakup of the Soviet Union, the growing cooperation between the U.S. and the former Soviet republics and enhanced U.S. global prestige as a result of the Gulf War, have created an environment much more conducive to dealing with proliferation concerns and have permitted a more concerted U.S. policy focus on regional security issues -- in the Middle East, in Korea and in South Asia -- as well as new initiatives to step up international nonproliferation efforts. This new focus is most evident in the President's nonproliferation initiatives in the Middle East and in Korea and in parallel U.S. diplomatic efforts to initiate a process of normalization of relations in these regions, and in South Asia, to reduce instability and the likelihood of conflict.

Unfortunately, the favorable political change in Eastern Europe and the Soviet Union has also created new security problems. New political freedoms have served to rekindle old wounds and ethnic rivalries, resulting in clashes between ethnic groups and the possibility of civil war. The breakup of the Soviet Union into a number of the new republics, some with large arsenals of nuclear weapons on their territory, has been of special concern. The reported completion of the withdrawal of all tactical nuclear weapons in the former Soviet Union to Russia and recent commitments in the context of signing the START Protocol by Ukraine, Kazakhstan and Belarus to eliminate all nuclear weapons, including all strategic weapons, on their soil by the end of the decade and to join the NPT as nonnuclear weapon states at the earliest possible time is encouraging. In addition, Administration and Congressional efforts to help the new republics accelerate dismantlement of weapons and to prevent a "brain drain" of nuclear and other scientific expertise to countries of proliferation concern is a very positive and needed initiative. These efforts, hopefully, will be successful over the long-term in reducing the proliferation risks associated with the Soviet breakup. However, at least for the time being, Eastern Europe and the various components of the former Soviet Union must be added to the list of areas of potential instability and proliferation concern.

Elements of an Approach

Dealing with proliferation and regional security concerns will require a step-by-step process involving cooperative actions both by the countries in each region and those outside the region. The necessary elements to support this process include:

- **A body of nonproliferation treaties and other institutional mechanisms** that provide an internationally agreed norm of behavior and a framework for regional parties to accept nonproliferation obligations;

- **Broadly accepted export control regimes** to help stop the flow of materials, equipment and technology to produce these weapons into regions of concern;

It should be recognized that nonproliferation treaties and export controls by themselves, however, can not prevent proliferation. Rather, they buy time to permit other, more direct efforts to deal with the underlying regional security problems that provide the incentives for proliferation. These more direct efforts include:

- **First and foremost, development of a political dialogue** and willingness of the parties in the region to seek a basis for peaceful coexistence and to reduce the risk of conflict;

- **Institution of appropriate confidence and security building measures (CSBMs)**, negotiated and agreed by regional parties, and monitoring systems to help verify dispute settlements. These should not only serve to improve the political climate, but also contribute in a significant way to reducing the risk of surprise attack and of conflict through error or miscalculation. These CSBMs need to be followed by:

- **Negotiation of arms limitation, reduction and elimination agreements**, with scheduled draw-downs of forces that establish a stable balance of conventional forces in the region, and that effectively preclude a successful attack that would threaten the survival of any other regional party; and, finally,

- **Acceptance of nonproliferation commitments** by parties in the context of international treaties, or on a regional basis, to forego weapons of mass destruction and the means to deliver them, combined with arrangements for elimination of existing capabilities.

These elements taken together provide a structure and, admittedly, an ambitious game plan for addressing regional security issues and dealing with proliferation problems. This is not to say that progress on nonproliferation can only be made in the context of resolution of regional security issues. Bilateral and multilateral security assurances may persuade some states to make commitments to forego nuclear and other weapons of mass destruction. But, sustaining these commitments over the long-term will likely require acceptable long-term solutions to regional problems. In any case, whether and to what extent events in a given region can successfully follow this game plan will be a function of the political will of the regional parties to find solutions to security issues, the nature of these issues, and the willingness of the U.S. and other interested states outside the region to support resolution of these issues.

Filling the Gaps

I am encouraged by the fact that the Administration with the support of the Congress, in addition to efforts to assist the republics of the former Soviet Union, has moved out quickly on a multi-pronged effort to deal with security and proliferation issues -- in the Middle East, in Korea and in South Asia. Many of the above elements are in place or are being developed. There are, however, some important gaps in the above framework. I will focus this morning on those elements most directly related to nuclear proliferation.

I. Nonproliferation Treaties and Other International Mechanisms

With regard to supporting and strengthening existing international mechanisms, the U.S. needs to:

- **Begin now to focus on ensuring extension of the NPT.** The Nuclear Nonproliferation Treaty (NPT) is central to U.S. and international nonproliferation efforts. The Treaty provides a norm for international behavior, a basis for imposing safeguards and export controls on nuclear supply, and an internationally accepted framework for regional parties mutually to forswear nuclear weapons. As required by Article X of the NPT, a conference is scheduled for 1995 "to decide whether or not the Treaty shall continue in force indefinitely, or shall be extended for an additional period or periods." With the concern about control of the nuclear weapons in the former Soviet Union, as well as the increasing focus of U.S. security policy on preventing proliferation and improving regional security, extension of the NPT has become an even more critical element in U.S. overall security efforts.

The U.S. goal for the Extension Conference should be an indefinite extension of the NPT, or at a minimum, extension for a series of periods of extended duration (e.g., 25 years periods). Achievement of this goal will depend to a large extent on the thoroughness of our preparation, both substantively and tactically, in dealing with the likely conference issues. These include negative and positive security assurances and possible linkage by some countries of NPT extension to progress in arms control, in particular, a comprehensive test ban. Although none of the potential issues should be showstoppers, it is necessary that the U.S. begin now, through a comprehensive program of bilaterals with other key countries, to lay the groundwork for a positive outcome.

- **Seek to conform verification regimes**, and in particular, challenge or suspect site inspection rights and procedures under the various nonproliferation treaties. The Iraqi situation has provided a number of important lessons with regard to treaty verification. One important lesson is that a monitoring system constrained to inspection of declared facilities is only capable of detecting and therefore deterring covert activities at such facilities. Even so, this is not a trivial inspection capability. It clearly does make cheating more difficult since such declared facilities often represent the easiest and least costly routes to proliferation. However, such a verification regime does not deter covert development of nuclear weapons at undeclared facilities.

To deter covert activities at undeclared facilities, nonproliferation treaties must provide for challenge inspections of suspected activities on a timely basis. Although the NPT, the Bacteriological Warfare (BW) Convention and Chemical Weapons (CW) Convention either have explicit provisions (as in the case of the draft CW Convention) or general provisions for conducting such inspections (both the Statute of International Atomic Energy Agency, the general NPT safeguards agreement (INFCIRC/153) and the BW Convention contain language that could be used to support challenge inspections), the procedures for initiating and conducting such inspections are neither well developed nor consistent across the three agreements.

An approach that I would strongly recommend is to develop common procedures for suspect site inspections under all three treaties that would use the UN Security Council to adjudicate concerns about suspected activities and, as necessary, to direct special on-site inspections.

This would utilize the Security Council in a role for which it was originally envisaged and would build on its enhanced image in the new world environment. Elements of such a regime would include:

(1) a right of any party to challenge the activities of another party if it suspects activity in violation of treaty obligations (as currently in all three treaties);

(2) submittal of a formal complaint and request to the UN Security Council for a challenge inspection by the appropriate international inspectorate, to include evidence supporting the validity of the accusation (as in the BW Convention); and

(3) detailed procedures for challenge inspection of suspected facilities and activities by an appropriate international inspectorate, without a right of refusal and without a right to deny reasonable access (an earlier form of the CW Convention obligation).

An approach incorporating the above elements would have several advantages:

(a) the regime would be common to all three Treaties, with a precedent in existing Treaty language (Article VI of the BW Convention and paragraphs 73 and 77 of the NPT Safeguards Agreement) and a basis for referral of cases of concern to the UN Security Council as provided in all three Treaties (the IAEA Statute, Article VI of the BW Convention and Article XII of the CW Convention);

(b) it would either permit accomplishing a challenge inspection on a timely basis -- thus helping to deter covert activity -- or cause the proliferator to deny access and thus be in violation of the Treaty; and

(c) through the exercise of our UN Security Council veto, the regime should adequately protect the U.S. from frivolous or intelligence-gathering challenges not associated with Treaty obligations.

- Fill gaps in U.S. intelligence assets, particularly in the human intelligence area, to better deal with regional proliferation problems. Although overhead systems can provide large amounts of valuable data, analysis of this data on a timely basis requires that the analyst knows where to look. This almost always depends on the availability of HUMINT. U.S. capabilities in this area have been drastically reduced over a period of years and need to be vigorously reestablished.

II. Export Controls

In the area of export controls, the U.S. and other industrialized supplier countries have supplemented the nonproliferation treaty structure with less formal arrangements, consisting of conformed export policies to deny certain exports and to reduce proliferation risks associated with other exports to potential proliferators. These export control arrangements include the **Nuclear Suppliers Group Guidelines**, which call for application of IAEA safeguards to an identified list of export items as a condition of supply, with a strong presumption to deny the more sensitive fuel cycle materials, equipment and technology to countries of proliferation concern. This export regime was a precursor for other nonproliferation-related export control regimes, including the **Missile Technology Control Regime** and the **CW Export Control Regime**, the latter which, hopefully, soon will be expanded to also cover BW-related exports.

Recommended U.S. actions to correct some major gaps and shortcomings in the nuclear export control area include:

- **A continuing, concerted effort by the U.S. to work with other countries to establish and implement effective national export controls.** Historically, the primitive nature and, in some cases, the absence of export control mechanisms in other countries, even in the more industrialized countries, has been a problem. In the nuclear export area, for example, a key function for the U.S. has been to assist countries in establishing effective internal mechanisms for screening and controlling nuclear-related exports. This function should be enhanced and expanded to include CW, BW and missile technology. We also need to step up our efforts to work with potential new suppliers. Nowhere is this need more urgent than in the former Soviet Union. Although a mature export control structure is in place in Russia, having adopted the Soviet Union's existing infrastructure, this is not the case in the other republics. This is a particular concern with regard to Ukraine, with its extensive nuclear facilities and weapons production capabilities. Moreover, all of the republics with nuclear facilities appear to need assistance in the area of internal nuclear materials control and accountability. Although the "brain-drain" problem is important, in the nuclear area, our ability to slow proliferation is at least as dependent on constraints on materials and equipment needed to produce nuclear weapons as it is on constraints on know-how. Thus, the need to assist the former Soviet republics in establishing effective materials control and accountability programs and export controls on nuclear exports and other proliferation-related exports deserves immediate attention.

- **Integration and coordination of export control regimes.** Because of the esoteric nature of the various areas of proliferation concern, national governments have tended to build separate bureaucracies in each weapons proliferation area. A significant reorganization of activities within agencies of the U.S. Government (which, to some degree, is already underway), and between the U.S. and other cooperating governments, would help to consolidate consideration of nonproliferation policy and initiatives and address intelligence sharing across the spectrum of nuclear, CW and BW, and missile proliferation issues. A streamlined nonproliferation bureaucracy also needs to coordinate closely with regional security affairs offices to ensure effective integration of nonproliferation, regional arms control and other security-related regional efforts.

- **Efforts to upgrade internationally-agreed export control lists**, to include new technologies and dual-use items, i.e., items that have both legitimate non-weapon uses as well as applicability to weapon development; this U.S. initiated effort is currently underway.

- **Greater use of intelligence assets on supporting U.S. export control efforts** and better arrangements for sharing relevant intelligence information with other suppliers. The intelligence community's recently established Nonproliferation Center is a positive step in this direction. But more needs to be done in terms of integrating the intelligence, technical and diplomatic resources within the U.S.Government to permit early identification of proliferation-related export activity and sharing intelligence with other countries to permit real time interdiction of exports of concern, while protecting U.S. sources and methods. And, *finally*,

- **Encouragement of emerging supplier countries to join these export control groups** or, at least, to adopt the export guidelines agreed by the groups. The bane of all export control regimes is suppliers outside the export control regime, ready and willing to provide controlled items to potential proliferators. Such circumvention, along with indigenous capability, is primarily responsible for the inability to date to effectively control the flow of missiles and missile technology. Supplier countries, such as China and North Korea, have been readily available suppliers of such technology in exchange for hard currency. The U.S. must continue to seek as a priority item to encourage responsible action by these second tier suppliers. In retrospect, it would have been prudent to have sought to include China early on in the various export control regimes, as we have decided to do with regard to conventional arms transfers to the Middle East. Such efforts are likely to be more successful in the case of emerging suppliers, such as Argentina and Brazil, who have espoused policies that support international nonproliferation efforts and indicated a clear interest in joining existing export control regimes. As a top priority, the former Soviet republics that have significant potential for export of items of proliferation concern should be encouraged to immediately join and actively participate in the Nuclear Suppliers Group and other export regimes. Economic assistance and cooperation linked to constraint in exports of proliferation concern may be the most effective tool in dealing with problem suppliers.

Regional Steps

As noted earlier, export controls, nonproliferation treaties and other institutional mechanisms by themselves cannot prevent proliferation. However, they can buy time to permit other, more direct efforts to deal with the underlying regional security problems that provide incentives for proliferation. These more direct efforts - establishing a continuing political dialogue between regional adversaries, a step-by-step process of negotiated settlements of disputes in combination with confidence and security building measures, and ultimately, stabilizing arms limitations and reductions and acceptance of nonproliferation obligations - must arise from within the region and be supported by the countries of that region. However, this process will almost certainly have to be catalyzed and nurtured by countries outside the region.

I. Political Dialogue

Getting the parties to the table with the necessary motivation to honestly seek ways to resolve regional issues and accept meaningful CSBMs is perhaps the most important and difficult step. In the U.S./Soviet and European context, significant progress in gaining agreement to meaningful CSBMs and arms control agreements occurred primarily in parallel with the major political changes in the East-West relationship. In the regional context, because of the history of conflict in most of the regions of concern, the process of promoting peaceful coexistence and political change will likely be even more difficult to begin, and once begun, to sustain. To the Administration's credit, it is seeking to establish the basis for such a dialogue in each of the regions of concern.

II. Confidence and Security Building Measures (CSBMs)

Assuming a basic political dialogue can be established between the parties, CSBMs are a logical next step in the process of improving regional security. They provide the framework for (1) promoting greater transparency and predictability regarding military activities of regional adversaries; (2) reducing capabilities and opportunities for surprise attack; and (3) providing the means for implementing negotiated arrangements for resolving territorial disputes. Typical CSBMs include hot line communications, data exchanges, observations and inspections as well as measures to reduce the likelihood of surprise attack, such as limits on where forces can be located near border areas and limits on the size and composition of these forces.

Some of these measures have already been implemented on a regional basis, e.g., in the Middle East in the context of the Camp David Accords, in South Asia between India and Pakistan and, hopefully soon, in Korea between the North and South, to include bilateral inspection of nuclear facilities.

Although the specifics of the measures must be tailored to each regional security situation, the underlying rationale is the same -- to improve the security of the parties by reducing the risk of inadvertent conflict or surprise attack and by increasing the transparency of potentially threatening activities.

Some major considerations for the U.S. in applying CSBMs to regional security problems include:

- **Development of Specific Proposals**: Although regional parties will ultimately shape the CSBMs, an initial package of CSBMs offered for negotiation will likely have to originate with a third party. This was our experience in the Camp David Accords and probably will be the case for each of the regions of concern. Emphasis should be on initiating and supporting a step-by-step negotiated process, modest at first, but leading progressively to more stringent security enhancement measures.

- **Role of the U.S.**: Because of its superpower status and, in many cases, its direct involvement in regional security relationships, the U.S. must play a leading role in all phases of the process - from establishing a basic political dialogue, to development of meaningful dispute settlements and finally, to implementation of CSBMs and arms control arrangements to reinforce them. In Korea, the U.S. is an active participant and viewed as an adversary by North Korea. In other cases, the U.S. can play a more neutral role, as it does in the Middle East talks -- facilitating the dialogue, and where necessary, helping to implement agreed CSBMs (as in the case of the Sinai). In any event, the U.S. will likely be involved in the negotiations and implementation of agreed CSBMs and, therefore, must be prepared to provide the diplomatic resources to keep the negotiations on track and the military and other support resources needed for implementation. Moreover, as in the case of the Camp David Accords, the U.S. and other industrialized countries may need to provide "sweeteners" in the form of a package of financial, technical and security assistance to improve the regional economic and security situation. As in all arms control efforts, the cost of implementing such agreements will be significant. However, this cost must be compared to the immeasurable costs of regional conflict -- in terms of dollars and lives -- as demonstrated most recently in the Iran-Iraq War and the Persian Gulf War.

III. Arms Control Limitations and Reductions

CSBMs, even in combination with the resolution of border and other territorial disputes, are not likely to provide sufficient assurance of regional stability and security to cause regional parties to forego proliferation options. Hopefully, CSBMs can lead to a freeze on such activity as part of the overall security arrangements. A reversal of proliferation, i.e., agreement to give up weapons capabilities already attained, more than likely can be achieved only in the context of agreements that establish a stable balance of conventional forces in the region and, thus, provide the necessary security for regional parties to accept nonproliferation constraints and destroy existing capabilities.

The CFE Treaty, with its multinational participation, is a useful model for regional agreements. The CFE Treaty elements, including the basic elements of the verification regime, in principle should apply to most regional negotiations. However, the wide variety of types of armaments and the marked differences in force structures and in the age and capabilities of armaments possessed by the various regional players compared to the situation in Europe, will make negotiations of force reductions and limitations necessarily complex and time-consuming. This will be particularly true in the multi-polar Middle East. Moreover, in each of the regions, the political will of the parties to seek a more stable balance of forces through negotiation remains an open question. The bottom line is that this element will be the most difficult to achieve but will likely be necessary if we hope to reverse proliferation in these regions of concern.

IV. Acceptance of Nonproliferation Constraints

Foregoing nuclear weapons capability and accepting nonproliferation constraints under the NPT or in a regional context will require a secure security environment and a government that recognizes the long-term security benefits of making such a commitment. In this context, it is easier to realize this goal if the countries of the region have not yet achieved a nuclear weapons capability. Thus, for example, the governments of Argentina and Brazil were able to effect positive changes in their nonproliferation policies to jointly abandon nuclear weapons-related activities and accept nonproliferation constraints. Urgent on-going efforts to get North Korea to abandon its nuclear weapons development program are aimed at achieving similar results.

The recent acceptance by the South African Government of NPT commitments, hopefully, is the first example of a situation where the security environment and government policies have come together to permit a reversal of an existing weapons program. However, whether such a reversal is achievable in the foreseeable future in either the Middle East or South Asia, given their current security situations, is highly problematic. Freezing the current situation will likely be easier to achieve than reversing proliferation. Thus, agreement by Israel not to go beyond current capabilities and similar commitments by India and Pakistan in South Asia, perhaps, in combination with commitments not to test nuclear explosives "for peaceful purposes" or otherwise, may be achievable in the near-term. A truly stable nonproliferation regime in these regions, however, will likely be possible only over the long-term and only in the context of stable conventional force balances and changed relationships between the countries of these regions. In the interim, stabilization of boundaries and other dispute settlements, combined with CSBMs to increase transparency and reduce the risk of surprise attack, arrangements for freezing current nuclear capabilities, and restraint by outside suppliers on exports of proliferation concern into these regions, hopefully, will provide the foundation and the necessary time for such change to occur.

Some Regional Considerations

Other papers this morning will address some of the specific regional considerations that need to be addressed to improve security and reduce proliferation incentives in regions of concern. Fundamental to each of these regions, however, is the need to establish a basic political dialogue and, once established, to proceed in a step-by-step process to resolve disputes and to implement measures to improve regional security. The U.S. will have to take a leading role throughout this process -- as catalyst for the talks; as joint host or participant in negotiations; and, in some cases, as a third party monitor or implementor of resulting dispute settlements. The U.S. has already taken the lead to establish such a process for the Middle East, invited the key players in South Asia, including China, to begin a similar process and taken initiatives regarding our military deployments in South Korea to provide the basis for dialogue and positive change on the Korean Peninsula. Progress in each of these regions will require that the U.S. continue to provide substantial resources -- technical, economic and military, as well as diplomatic.

We will also need to ensure the continued cooperation of Russia, other key supplier countries and others with security interests in each of these regions. Japan clearly is an important player because of its economic leverage, particularly with regard to Korea. China is equally important because of the key role it plays in each of the regions of concern. Unfortunately, its actions to date have not been supportive of either our nonproliferation efforts or our efforts to encourage regional players to resolve security issues. We and others will, therefore, need to convince China that it is in its long-term interest to make a more responsible and constructive contribution toward success of these efforts.

As a final point, underpinning the approach I have outlined is the premise that the U.S. Administration, the Congress and the Public are not only prepared to have the U.S. take the lead in helping to achieve negotiated settlements of regional security issues but to back it up with application of sanctions and military action, if necessary. This latter role will require that the U.S. maintain the necessary military posture and force structure to quickly project forces into regions of concern as well the weapon systems capable of deterring the use or threatened use of weapons of mass destruction in these regions. Of equal importance, the U.S. will also need to make clear in its declaratory policy and in its diplomatic communications conduct it will tolerate and conduct it will not -- something we have been less than successful at in the past.

Nonproliferation "Progress" in Korea: Next Steps

J. Grubb
Meridian Corporation

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INTRODUCTION

The sweeping historic changes of the past two years, including the reunification of Germany, the cessation of Communist control over Eastern Europe, and the collapse of the Soviet Communist Party and government in the former Soviet Union, have ended the bipolar U.S.-Soviet relationship that dominated world politics since 1945. Among the significant consequences of these changes is that there are now new opportunities to address volatile regional instabilities. In Northeast Asia (North and South Korea), in South Asia (India and Pakistan), and in the Middle East, these instabilities, have been, at best, relatively ignored as primary U.S. attention has remained focused on Soviet-American interactions. At worst, they were intensified and made more dangerous as the U.S. and the USSR continued their superpower rivalry by creating, arming, and supporting regional client states to oppose one another. This was the case in regard to the Korean Peninsula and, as a result, Northeast Asian arguably remains the most volatile of these unstable regimes.

Sources of Korean Instability

The instability impacting the Korean Peninsula springs from a number of sources. The two Koreas have diametrically opposed each other on an ideological basis for the past 40 years as the South developed a capitalist regime, and the North developed and maintained a rigid Stalinist regime even as Soviet communism was evolving to a less restrictive form. The North and South by their very existence also challenge the legitimacy of one another and this has led to an intense level of distrust, suspicion, and rivalry that may be even stronger than the level that existed between the U.S. and the USSR at the height of the Cold War. Both Koreas maintain large, standing armed forces that tensely face each other over a heavily fortified Demilitarized Zone (DMZ) and, as was seen in a May 22 armed clash resulting in the death of two North Korean soldiers,[1] the possibility for flashpoint escalation to open conflict continues to remain extremely high. This situation has certainly been worsened by North Korea's continued significant efforts to develop nuclear weapons, as well as chemical and biological weapons of mass destruction. North Korea has also significantly contributed to dangerous instability in not only Northeast Asia, but in other regions as it has sought to refine indigenously produced SCUD ballistic missiles to nearly double their range, and has sold the improved SCUDs to other unstable regimes in the Middle East.

Recent "Progress"

Despite these major sources of instability, North and South Korea have over the past year developed a significant political dialogue to replace what previously had been only a forum for the exchange of ideological diatribe. Economic forces have played an important role in this as Pyongyang's economy has steadily worsened. The Soviet Union, its previous major supporter, has fallen and Russia has indicated that it will not continue to subsidize

[1]*T.R. Reed, "North, South Korean Troops Clash on Border," The Washington Post, May 23, 1992, p. A16.*

North Korea. China, North Korea's remaining benefactor, has not been able to make up for the lost Soviet support. North Korea consequently approached Japan in 1990 to discuss economic cooperation. Tokyo has pursued closer economic ties with North Korea since that time, but has refused to finalize these ties until Pyongyang agrees to accept inspection of its nuclear facilities and halt its efforts to reprocess or otherwise acquire weapons-grade material.

Coordinated, innovative approaches from South Korea and the U.S. have also significantly assisted in improving the political dialogue between the two Koreas. The South set aside its previous inflexibility and presented new, serious negotiating positions to better its relations with the North. The U.S. apparently removed its nuclear weapons stationed in the South and, in conjunction with Seoul, agreed to the cancellation of their joint military exercise "Team Spirit" for 1992 -- both major concessions to address long-stated North Korean concerns. Washington, Seoul, Moscow, and Tokyo have also applied coordinated diplomatic and media pressure to convince North Korea to end its long-maintained isolation and become more forthcoming in its relations with other states in the Northeast Asian region.

The end result of this economic and political activity was the conclusion of a number of significant agreements between the two Koreas at the end of 1991 and in the first half of 1992. In December 1991, North and South Korea signed a nonaggression accord in which they agreed to (1) begin negotiations on a peace treaty; (2) form a joint military committee to discuss the issues related to nuclear weapons development and deployment; (3) ban terrorist activity and end attempts to overthrow the other's government; (4) set up liaison offices in Panmunjom to help reunite families separated by the division of the Peninsula; (5) and promote free trade and correspondence. The agreement also included the establishment of hot lines, advance notification of military exercises, and the transformation of the DMZ into a "peace zone."

In January 1992, the North and South signed another highly significant agreement that banned nuclear weapons from the Korean Peninsula and agreed to establish bilateral inspection procedures to verify that ban. After a delay of nearly seven years, North Korea also ratified a safeguards agreement with the International Atomic Energy Agency (IAEA) regarding inspection of its nuclear facilities in the middle of April 1992, released a documentary video tape to the world media openly displaying its three nuclear reactors, and most recently has escorted the IAEA Director and a study group in a walk-through tour of its nuclear facilities.

North Korea's Motives

The nuclear-related elements of this activity, however, have monopolized attention as the real meaning of North Korean actions has been hotly debated over the past few months. Some experts point to public CIA estimates that North Korea could produce a nuclear weapon in a timeframe "from a few months to several years."[2] Citing demonstrated North

[2]George Lardner, Jr., "North Korea Might Conceal Atom Arms, Gates Says," The Washington Post, February 26, 1992, p. A-20.

Korean intransigence to follow through from the recent joint nonaggression and denuclearization agreements and conclude actual arrangements for inspection of its nuclear facilities as quickly as possible, they argue that what has happened in the past eight months cannot be termed progress. Instead, the agreements are being used to stall and give the North time to develop and hide nuclear weapons before allowing the inspections to proceed. Others argue, however, that although the North apparently had undertaken a significant program to develop a nuclear weapon, it has now decided instead to forego that program. The delay in opening its nuclear-related installations to inspection is understandable given the dramatic change that Pyongyang must accept in order to move from a closed society to a point where they can accept on-site inspection. Another major reason for the delays is for North Korea to demonstrate its sovereignty in the face of the pressure tactics exerted by the U.S. and its allies.

Purpose and Scope

The purpose of this paper is not to enter into this current interpretative debate regarding North Korea's efforts to develop nuclear weapons. (For this reason, the nonproliferation "progress" referred to in the paper's title has been placed in quotations until it can be clarified that the activity that North Korea has undertaken is either progress only in form, or whether it constitutes real forward movement.) Using this on-going debate as a starting point, the necessary next steps to effectively address the full range of North Korea's proliferation activity will be discussed in the following pages. This will include not only measures to consolidate whatever "progress" that has been achieved in regard to North Korea's nuclear proliferation, but also measures to address ballistic missile and chemical and biological weapon (CBW) proliferation. As an important part of this effort, an examination will be made of the tools and tactics available to achieve U.S. nonproliferation goals for Korea, including confidence and security-building measures (CSBMs) and arms reduction agreements, as well as the appropriate fora in which U.S. nonproliferation efforts should be taken.

DENUCLEARIZATION OF THE KOREAN PENINSULA

It is appropriate to begin an analysis of the various sources of instability affecting the Korean Peninsula, and how they should be addressed by the U.S., with an examination the extensive efforts by North Korea to develop a nuclear weapon. Concern over this proliferation activity by the North has dominated the U.S. Government's attention with regard to Northeast Asia for the past several years. Arguably, this fixation is well-placed when taking into consideration Pyongyang's diplomatic, political and ideological isolation, and confrontational manner of dealing with its problems. It may also be argued, however, that the U.S. fixation on North Korean activity to develop a nuclear weapon has detracted from other efforts to address Pyongyang's proliferation in other areas, including the development and sale of ballistic missiles and chemical and biological weapons (CBW) to unstable regimes in other regions, that are also seriously destabilizing.

North Korean Nuclear Development Activity

Still, North Korea's attempts to build a nuclear weapon have been both focussed and extensive. According to a September 1991 article in Jane's Intelligence Review, in 1965 North Korea received from the Soviet Union a two-to-four megawatt (mw) research reactor and installed it at Yongbyon. North Korea subsequently increased the reactor's capacity to eight mw using its own technology. In 1980, North Korea began construction of an indigenously-designed reactor based on a 1950s-era British designed reactor. This 20-30 mw reactor uses graphite, which North Korea produces locally, to control nuclear reaction. U.S. satellites have reportedly picked up images of another facility containing a larger 50-200 mw, reactor, which is expected to begin operation in early 1992. The size of this reactor and the fact that it is not connected to a power grid was believed to indicate it is to be used in production of nuclear weapons materials. Most significantly, North Korea is believed to possess a reprocessing facility which is expected to be operational in a 1994-1995 timeframe, and which would permit North Korea to extract weapons-grade plutonium from spent nuclear fuel. These two new facilities are located at Yongbyon and appear to have been constructed without Soviet or Chinese aid. North Korea is believed to have garnered western aid in efforts to develop them, however, and has obtained certain crucial materials from Germany and other sources.[3] Based on European satellite photos, some media experts have reported the probable existence of yet another North Korean nuclear facility at Pakchon in Pyongan province.[4]

U.S. Nonproliferation Efforts

In its recent efforts to address North Korea's nuclear weapon development, the U.S., in conjunction with its allies, has generally pursued a "stick and carrot" approach. Working closely with Japan, in coordination with the new Russian government, and somewhat less with China, the U.S. has continued to place political, diplomatic, and media pressure on Pyongyang to forego its nuclear development activity. This has been strongly reinforced economically by Japan, as discussed in the Introduction section. The "carrot" used involved U.S. concessions regarding the reported removal of its nuclear forces based in Korea, and concessions on the part of the U.S. and South Korea to cancel "Team Spirit, 1992," also discussed earlier. This activity is believed to have directly resulted in the North jointly pledging with the South in December 1991 to not possess, manufacture, or use nuclear weapons, and not to possess reprocessing and uranium enrichment facilities. Outwardly, this amounted to formal agreement on the denuclearization of the Korean Peninsula by the North and should serve to end this source of instability. What continues to give the U.S. and its allies significant pause, however, is a clearly demonstrated North Korean reluctance to set in motion the sets of measures necessary to verify Pyongyang's compliance with the Joint Declaration for a Nuclear-Free Korean Peninsula, and its compliance with the Nuclear Nonproliferation Treaty (NPT) signed in 1985.

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[3] *Joseph Bermudez, "North Korea's Nuclear Programme," Jane's Intelligence Review, September 1991, pp. 406-409.*

[4] *"North Korea May Have Second Nuclear Base," The Washington Times, October 30, 1991, p. A11.*

International (IAEA) Inspection Developments

The first set of measures concerns the inspections associated with an IAEA safeguards agreement that Pyongyang publicly declared it would sign and implement in November 1991, after over a six year delay following North Korea's accession to the NPT in 1985. Pyongyang has subsequently heated up, and cooled down, efforts to reach agreement on the details necessary to establish and implement a safeguards agreement, including a delay of several months to wait for the rubber-stamp North Korean People's Assembly to meet and deliberate whether the safeguards agreement should be ratified. The North's efforts with regard to these IAEA inspections now seems to have again moved into an active phase. Pyongyang is presently exchanging data with the IAEA necessary to work out inspection agreements for each of its declared facilities, primarily in response to strong U.S. and UN pressure. The Director of the IAEA has just visited North Korea's nuclear facilities and it now appears likely that the first IAEA inspection may take place in advance of the mid-June suspense set by the U.S. and its allies, after which they threatened to impose U.N. sanctions on North Korea. The key question remaining, however, concerns which specific sites will be inspected. IAEA inspections are conducted only at agreed, declared facilities. The North and the IAEA have not yet announced final agreement on those nuclear-related facilities to be included. What has been publicly reported, however, is that after years of denial, the North has finally admitted that it has extracted plutonium at the facility that the U.S. believes is a reprocessing plant. The North Koreans, however are insisting that it is not a reprocessing facility and terming it only a "research laboratory". If agreement is not reached on including this specific facility as a declared site for IAEA inspections, it will not be visited. Under the terms of the NPT, there is no explicit provision for suspect-site or challenge inspections of other than declared sites. The IAEA statute and the generic basis for IAEA/NPT Safeguards Agreements (INFCIRC 153) do provide for the possibility of a special challenge inspection, with referral of possible violations of the safeguard agreement to the UN for follow-up action, but such an inspection has never been invoked. Even if such an inspection could be prepared for the first time in IAEA history, it would still require acquiescence on the part of Pyongyang to take place.

Bilateral Inspection Developments

The second set of measures involve the bilateral inspection procedures that the North and South agreed to establish in conjunction with the Joint Declaration. Progress on these procedures has also been slowed by the North, and resulted in a delay in their negotiation. The North rejected South Korean proposals for early a "pilot" bilateral inspection, even on a walk-through basis of suspect sites. North Korea also concurrently leveled a number of demands on the South in the media, including a demand to inspect South Korea's military bases to confirm that U.S. nuclear weapons had been removed prior to accepting any inspections of North Korean facilities. The confusion over this apparent "walk back" by Pyongyang from a previous position of bilateral, simultaneous inspections delayed progress for weeks. The two sides finally agreed in March on a timetable for establishing inspection procedures, and to begin mutual inspections by June 10. The Joint Commission to address these procedures finally met for its initial session on March 19. Any progress that may have been achieved to date has not been reported publicly.

In February, however, the Washington Times reported new indications of the construction of deep tunnels around the North Korean Nuclear site at Yongbyon, possibly to hide nuclear development activities from IAEA inspections which are expected to occur prior to the bilateral inspections. Both the U.S. and South Korea have publicly charged that the North is stalling the bilateral inspection talks, and attempting to carefully control and restrict IAEA inspections, in order to be able to produce and hide or transfer weapons-grade nuclear fuel undetected by on-site inspection activity.

Tools, Tactics, and Fora Available to the U.S.

The present situation leaves the U.S. and its allies in a somewhat awkward situation. They have achieved a formal and official pledge by the North Korea on the denuclearization of the Korean Peninsula. It remains unclear, however, whether North Korea really intends to honor the Joint Declaration. The publicly announced U.S. goals are therefore to ensure (1) as an interim measure, that viable and effective on-site inspections can be carried out by both the IAEA and the South; and (2) as an ultimate goal, that the apparent North Korean reprocessing plant is dismantled. Tools to use in accomplishing these specific goals, and the fora where the tools may be applied, could include the following:

- **Increasing the political, economic, and media pressure on North Korea** by the U.S. and other regional states with a major interest, including Japan, Russia and to a lesser extent China. China's participation is expected to be limited because the Chinese have complained about previous bilateral pressure on Pyongyang by the U.S. and others, arguing it is ineffective and an insult to North Korea's sovereignty. Japan may have the best card to play in exerting pressure on the North -- promises of economic assistance -- if Pyongyang's economy continues to do poorly as expected.

- **Conducting a multinational conference of major regional powers** to address denuclearization of the Korean Peninsula and Northeast Asia. Invitees again should probably include the U.S., Japan, China, and North and South Korea. The general thrust of the conference would be to try to pull Pyongyang further out of its isolation and coopt it into acting with the others to address regional security. The clear challenge would be to conduct the conference without singling out North Korea and causing Pyongyang to feel that it was being coerced by all of the other participants. Many observers continue to feel, however, that such a conference could be highly successful if carefully conducted, and might prove effective in certain areas where political, diplomatic, and media pressure has been counterproductive in the past.

- **Attempting an IAEA special challenge inspection.** This measure would involve two unknowns. Having never attempted a special inspection in the past, the IAEA will have to carefully "set the stage" to carry out its first. Attempting to mount a special inspection may well draw the criticism of certain UN members who might be concerned that they could receive such an inspection in the future. The second, even more significant unknown is whether North Korea would accept a special inspection. If Pyongyang flatly refuses to accept an IAEA team in a special inspection status, then practically speaking, the inspection will never occur.

- **Restarting "Team Spirit" joint military exercises with the South.** This action may more symbolic than anything else, but could serve to underscore that the improved conditions on the Korean Peninsula which permitted the cancellation of Team Spirit for 1992 are no longer felt to exist by the U.S. and the South. A drawback to this action is that it could have the effect of stiffening the North's resolve not to cooperate. North Korea has long attacked Team Spirit, bitterly claiming that it is an exercise of nuclear attack plans against the North by the U.S. and South Korean military. Reinstitution of Team Spirit could also push the North into stepping up the pace of development of its own nuclear weapons in self defense.

- **Enforcing U.N. sanctions through an air and naval blockade** to implement an economic embargo against the North. The blockades would similar to those imposed against Iraq following the invasion of Kuwait. If effective, such an action could have a serious impact on North Korea's already weak economy and could serve to underscore North Korea's isolation. It could also push the North into military actions in response. A key to the success of such sanctions would be the participation of China, who has already condemned much less severe forms of pressure on North Korea. Without China's full participation, the effectiveness of any blockade of North Korea would probably suffer in application.[5] Even with China's complete support, the blockade would probably have to be carried out for months, if not years, to be effective. Further, as was seen in the blockade of Iraq, the longer the action was required, the more difficult it became to sustain.

- **Imposing G-7 Sanctions.** G-7 economic sanctions, joined by Russian, could also be used to pressure North Korea, and would probably be effective with regard to North Korea's imports. The advantage of this measure is that it avoids the necessity to gain China's support. To be effective, however, Japan would need to find a way in the face of expected strong domestic opposition to cut off the flow of money and capital to Pyongyang from the pro-North Korean segment of the ethic Korean community in Japan.[6] A major drawback of the G-7 sanctions is that they, like U.N. sanctions, would have to be imposed for months, if not years, to have serious effect. Arguably the longer such sanctions are imposed by G-7 members against North Korea, the longer they will come under attack by Third World states as the worst form of imperialism.

- **Mounting further military pressure** that could range from:

  -- **surgical air strikes.** As Israel demonstrated in its 1981 attack on Iraq's Osirac nuclear reactor, a surgical strike on North Korean's reactors and reprocessing plant during the phases before a nuclear weapon is fully developed can be effective in retarding such proliferation efforts. If Pyongyang has hidden some of these developmental facilities as some

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[5]*Larry Niksch, "North Korea's Nuclear Weapons Program," Congressional Research Service, April 8, 1992, p.12.*

[6]*Niksch, "North Korea's Nuclear Weapons Program," p. 13.*

observers believe, however, the flaw in this measure is that it might not be totally effective. Moreover, it could likely result in retaliation by North Korea against targets in the South, or perhaps even full-scale invasion.

-- **to a build-up of U.S. conventional and nuclear forces in and around Korea.** Such actions might deter a Northern invasion, and reassure the South, but the likelihood that U.S. forces would have to remain in place for an extended period would be high. They could also be subject to North Korean attack, either directly or through terrorist actions. A force build-up would also add several billion dollars annually to the cost of U.S. forces in the Western Pacific[7] at a time when the U.S. government is trying to sharply reduce military spending.

CONFIDENCE AND SECURITY-BUILDING MEASURES (CSBMS)

Another major source of instability impacting the Korean Peninsula is the suspicion, mistrust and misunderstanding that has existed between the two Koreas for the past forty years. As discussed in the introduction, the sources for these feelings are varied and range from the diametrically different types of society involved (Stalinist versus capitalist), and that the very existence of the governments of South and North Korea is a challenge to the legitimacy of the other. A tool that may material assist the U.S. in addressing this source of instability are confidence and security-building measures or CSBMs.

In general, CSBMs include measures generally designed to reduce mistrust and misunderstandings about opposing state's military capabilities and intention and increase openness and predictability in the military environment. They can be applied to create a framework for reducing suspicion, and serve as catalyst for moving opposing States toward a more permanent resolution of differences such as territorial disputes. CSBMs can be grouped into three general categories:

- **Transparency and Predictability.** These measures involving data exchanges on military force structure, armaments, and advanced notification of major exercises, involving pre-announcement of their location, size, and duration.

- **Observation and Inspection.** These measures involve a continuum that range from opposing States conducting simple observation of each other's major military exercises, and moving to more intrusive aerial or on-site inspection of one another's military activities as progress is possible. These CSBMs will serve as a foundation upon which the opposing states can base a more intrusive on-site inspection regime if agreement is reached in the future on arms reductions measures.

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[7]Niksch, "North Korea's Nuclear Weapons Program," p. 13.

- **Conflict Prevention and Crisis Management.** Such measures establish a framework for opposing states to communicate with one another during crisis situations, and provide a tool to be used in preventing a crisis from escalating into open conflict.

CSBM Application in Korea

CSBMs have been successfully negotiated and implemented in Central Europe as tools to increase openness and reduce mistrust in the U.S./NATO and USSR/Warsaw Pact context. They address, however, security problems that are not unique to Europe. As discussed in the Introduction section, the intensity of mistrust and antagonism on the Korean Peninsula resembles that which existed between NATO and the Warsaw Pact in Central Europe, which CSBMs materially assisted ı defusing. These similarities lie in the following general areas:

-- Large standing military forces of North and South Korea face one another across the world's most heavily fortified, contested borders amid old and persistent tensions.

-- With such a concentration, there is a continued risk of premeditated conflict.

-- There is a continuing risk of accidental conflict due to a miscalculation or misunderstanding over normal military activities, as was seen in the most recent border skirmish that resulted in the death of two North Korean soldiers,

-- And, finally, should conflict occur, there is a real danger of escalation to weapons of mass destruction.

Crucial to the successful application of CSBMs in Korea will be the motivation of the opposing states. CSBMs cannot be imposed by outside parties and there must be continuing political will on the part of both North and South Korea to undertake CSBMs if they are to be successful. There are present indications that this will exists. Both Koreas have considered a role for CSBMs over past years of negotiation, with the South supporting an approach in which CSBMs would be the one of the initial tools used to improve relations between the two states, and the North resisting, but primarily only in regard to timing. This resistance on the part of the North may have been overcome by the details of the December 1991 Joint Agreement which established a number of measures that constitute CSBMs. These included the creation of a "hot line" between the two Koreas for crisis management and conflict prevention, agreement on advance notification of major military exercises, and agreement to transform the heavily fortified Demilitarized Zone into a "peace zone."

In addition to political will, CSBMs must be tailored, as much as possible, to take into account the peculiarities of the Korean Peninsula in order to be most effective and viable. One way in which they must be made unique to Korea involves the time sequence of their application vis-a-vis efforts to reach agreement on arms reductions. In Europe, CSBMs were negotiated and agreed simultaneous with negotiation of the CFE Treaty for reductions of conventional armed forces. Although the European CSBMs have been implemented while awaiting for the entry into force of the CFE Treaty, there was still a synergistic effect between the two agreements that made each easier to negotiate. For reasons more fully explained in the following section, the disparities of the conventional force balance in Korea seems to dictate that CSBMs would probably be agreed to and implemented well in advance of a conventional arms reduction treaty. This pathbreaking role, therefore, needs to be taken fully into account when tailoring CSBMs to the Korean Peninsula. Suggestions for tailoring specific Korean CSBMs from the three general categories of confidence and security-building measures are discussed in the following paragraphs.

Transparency and Predictability Measures

In the area of predictability, measures of specific value are CSBMs that result in an information exchange on military force structure and equipment. To begin, the North and South could each agree to identify for the other the basic structures of their military forces, and declare holdings of major equipment items. This can be expanded from a simple initial exchange to providing one another with greater detail, including the locations of major headquarters and units and more detailed data on equipment holdings. These exchanges could be updated annually and could eventually be expanded to encompass data exchange on major new weapons deployments, including both arms indigenously produced and those purchased from other states. Another transparency measure that could be instituted would involve military-to-military exchanges concerning one another's doctrine and budget, creating a better understanding of each other's capabilities. CSBMs relating to constraining major military exercises to a certain agreed troop and/or equipment level are also of value in increasing transparency and predictability. To be effective, the North and South could agree to cease all exercises above certain level. Advance notification could also be required of large-scale ground forces exercises below this level, a measure already apparently agreed in the December 1991 nonaggression accord. In establishing these types of notification measures, the principle should be to go from the simple to the more complex. This could mean an initial requirement to only notify the other side at some limited time in advance of an exercise, and to provide a general description of the duration of the exercise and its rough scale. The two Koreas could eventually progress to a long-term (e.g. annual) exchange of exercise schedules, and agree to further size limitations and/or limitations on the exercise's geographic limitations and duration.

Observation and Inspection

In these types of CSBMs, the principle is to move from the simple, and more easily agreeable measures, to more complex and intrusive measures. North and South Korea could agree to begin with less contentious observations of pre-announced military exercises. The Koreas could exchange observers for such exercises to determine whether exercise size constraints were followed. Another observation measure would be to institute an exchange program of military officers to be assigned with each other's key units, a measure previously discussed between the North and the South. From this simple beginning, they could move to more detailed inspections. One possibility would be for the North and South to accede to the Open Skies Treaty or agree on a bilateral aerial inspection regime. Another could involve agreement on an annual quota for inspections of a limited period of time (e.g., 24 hours), that could be conducted at specific units of the other state, stationed at or near the Demilitarized Zone. The level of unit to be inspected would have to be tailored according to the particular force structure of the North and South.

Conflict Prevention and Crisis Prevention

As noted above, the Koreas have already agreed to establish one communication means -- a "hot line" -- to assist in conflict prevention and crisis management. Another related CSBM would be to establish a link to pass data exchanges on forces agreed as transparency and predictability measures. Given past recent history, including the "tree-cutting" incident in the late 1970s, establishment of procedures to formalize the management of accidents, border incursions, and dangerous incidents between the two Koreas could materially assist in avoiding conflict escalation during future such events.

Another CSBM related to conflict prevention that may be applicable to the Korean Peninsula involves agreement on and establishment of border monitoring posts. As is discussed more fully in the following section, the defense of Seoul is of critical concern to the South, primarily due to its proximity to massive North Korean force concentrations on the border and the lack of defensive terrain between the border and Seoul. Border monitoring posts may help in some degree to allay these concerns for the South.

Role for the U.S.

Having stressed above that CSBMs cannot be imposed in an unstable region by outside states, it is important to close this section with a brief discussion of the most effective role for the U.S. in instituting CSBMs on the Korean Peninsula. If the major requisite is present -- political will on the part of North and South Korea to accept CSBMs -- there is still a problem of education. European CSBMs were agreed only after years of negotiation. To help improve the stability of the Korean Peninsula on more timely basis, and to avoid having the Koreas spend a like period of time conducting CSBM negotiations, the most effective role for the U.S. to play is as an educator and facilitator. As has been demonstrated in the negotiation of the Sinai Accords involving Israel and Egypt in the early 1970s, it is easier for two states that have long regarded each other with hostile intent to consider ideas and concepts offered by a third party. In its role as the remaining superpower, and as a state experienced in arms control, the U.S. will probably need to play a leading role in all aspects of negotiating and implementing CSBMs for Koreas to ensure timely agreement and implementation. This may range from simply educating the North and South on CSBM measures, to offering "strawman" proposals to stimulate progress, to providing technical expertise regarding the implementation of agreed measures. One related unknown concerns Pyongyang's acceptance of the U.S. in such a role. If the U.S. is unacceptable as a facilitator, North Korea will still need to be advised regarding CSBMs in order to achieve mutual progress and agreement with the South. A possible solution would be for the U.S. to prevail upon Russia to act as an advisor to the North instead. Russia has the arms control experience to perform well in this role, is arguably much more acceptable to the North than the U.S., and is apparently be willing to serve in such a capacity.

CONVENTIONAL ARMS REDUCTIONS

As discussed in the Introduction, the Korean Peninsula closely resembles the heavily armed conventional standoff that was present in Central Europe throughout the Cold War. The close proximity of the massed forces of the North and South along the most heavily fortified border in the world makes accidental conflict and escalate to use of weapons of mass destruction a daily possibility. Further, regardless of how effective a package of CSBMs is negotiated and implemented for the Korean Peninsula, it is highly unlikely that true regional stability can be established until an arms reduction agreement is reached between the North and South to reduce their forces to more stable conventional levels. It is necessary to examine some of the aspects of the present conventional imbalance, however, in order that the enormity of the conventional threat, and the need for conventional reductions, is more clearly understood.

North Korea

According to The Military Balance 1991-1992,[8] North Korea has approximately 1,111,000 active troops, and over 1,000,000 of those are in the army. The government is believed able to mobilize up to an additional 500,000 ground forces troops and 40,000 personnel in the reserve naval forces in 12 hours. There are also an estimated 200,000 security troops that include border guards, and 3,800,000 members of the Worker Peasant Red Guard. As in any consideration of troop strength, however, the issue of the quality of these paramilitary forces needs to be appraised in order to determine their military significance.

According to media statements by South Korean officials, the North Koreans have continued to upgrade their field artillery, SSM and SAM systems, ground attack helicopters and main battle tanks. The Korean People's Army (KPA) is believed to have added a fifth mechanized corps, along with over 300 main battle tanks, 600 towed artillery and 100 combat aircraft, since the mid- 1980s. A significant weakness of the KPA is, however, that the majority of its combat equipment is dated, 1950s and 1960s technology.

[8] *The Military Balance 1991-92, International Institute for Strategic Studies, London, 1991, pp. 167-170.*

North Korea is believed to forward deploy about 65% of its ground forces close to the DMZ, and their deployment posture is appears to be offensive in nature, indicating a continued capability for a massive frontal assault on Seoul along the Western corridor of the DMZ.[9]

South Korea

South Korea has only approximately 750,000 active forces; 650,000 of these are in the army. The South Korean military is judged to have a technical advantage over the North in areas of command, control, communications, and intelligence; combat aircraft; attack helicopters; precision guided munitions; and SAMs.[10]

The significant vulnerability of Seoul, South Korea's capital and home to 12 million people, continues to be of significant concern to the South. Seoul is believed by U.S. and South Korean military officials to be very vulnerable to the massive frontal assault that North Korea is capable of mounting across the DMZ. Only 30 km separate the heavily fortified positions of the DMZ and the northern outskirts of the capital, and very little of it constitutes defensible terrain. Concerns regarding this situation continue to appear in the public statements of South Korean government and military officials.

Past Negotiating Positions

Both the North and the South seem to realize the need for force reductions and have continued to raise the issue during reunification discussions. The North's concern is that the South, with continued assistance from the U.S., will be able to obtain military advantage over the NKA's outdated weapon systems over time. With its economy staggering and its previous military patron, the Soviet Union, gone, Pyongyang can see no way to compete.

The arms reduction proposals put forth by the North, however, have created significant concern for the South. The North has generally proposed that each side reduce at an equal pace to only 100,000 troops in three to four years. Equipment should be reduced proportionally. It is unclear whether this proposed 100,000 level includes reserves. Seoul is specifically concerned that the militarized nature of North Korea's society permits them to mobilize much more rapidly. If the North keeps a large reserve, Pyongyang can continue to rely on a significant numerical advantage after only a short period of mobilization. Further, if both sides reduce their standing forces at an equal pace, a situation could be possibly reached where the NPA still would have sufficient assets to mount an attack but the South Korean Army would have reduced below a level where the DMZ could by effectively defended, and Seoul could be overrun.

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[9] *Chung Min Lee, "Arms Control in the Korean Peninsula," The Washington Quarterly, Vol. 14, No. 3, Summer 1991, pp.182-183.*

[10] *The Military Balance, 1991-92, p. 183.*

In certain aspects, these two positions reflect a situation for the Korean Peninsula that is generally analogous to the force reduction challenge facing NATO and Warsaw Pact prior to negotiation of the CFE Treaty.

-- Two heavily armed forces face each other across a heavily fortified border and the need to reduce these forces to improve security is clear to each side.

-- To ensure that the security of each side is maintained, asymmetrical reductions are required to reach parity at lower force levels.

-- To improve regional stability, there is a need to verify that the reductions are carried out in accordance with their agreement and that the agreed lower force levels are maintained.

The CFE Treaty as a General Model

Given the similarities in the situation now in Korea and previously in Central Europe, using the CFE Treaty as a general model to address Korean force reductions seems appropriate. A key concept from the CFE Treaty can serve to resolve South Korea's concern regarding the North's well-developed reserve system. Rather than tying reductions to personnel, who would remain military assets even if out of uniform, it is more effective to use combat equipment as the unit of accountability for reduction activity since equipment is easier to verify. The reductions can even be concentrated to enhance security by reducing key equipment that is used in offensive combat operations, e.g., battle tasks, artillery, armored combat vehicles, combat aircraft and attack helicopters.

To assist in verifying equipment reductions, the North and South could exchange data in associated force structure, and on the location of the key combat equipment before, during, and after reductions. This data could be verified by on-site inspection. The destruction of excess items of key equipment over the agreed lower levels could be verified by on-site inspection as well, to ensure that this equipment is no longer available for use by reserves. Finally, to further address South Korea's concerns about the present force imbalance Northern concentrations along the DMZ and the defense of Seoul, the drawdown plan to agreed lower levels could involve a weighted, zonal approach. This would permit initial reductions to occur in the immediate regions on either side of the DMZ from where attacks would have to be staged, as well as provide a mechanism to tailor the equipment and forces permitted there after reductions to ensure a maximum defensive posture and a minimum offensive capability are retained.

U.S. Role

As with CSBMs, there must be political will between the North and South to engage in arms reductions. This will cannot be imposed from outside the Korean Peninsula. Based on their past discussions on this issue, there does appear to be a realization on the part of both the North and the South that arms reductions will be necessary to end a significant source of instability. With the catalytic effect of CSBMs, the necessary political will for reductions may be reinforced. If so, the key question again concerns what role should the U.S. play to assist the two Koreas in arms reductions.

As with the negotiation, agreement, and implementation of CSBMs, the U.S. can play a valuable role concerning an arms reduction agreement by educating the South and the North on the process involved and tools available, and providing technical assistance. Without educational and technical assistance, the two Koreas will be condemned to making the same mistakes, and probably taking a similar length of time, as was required to conclude the CFE Treaty. A major unknown again is whether North Korea would accept the U.S. in such a role as a mentor and advisor. If not, another mentor would have to be found, for it will not expedite matters to educate and assist only one of the parties to be involved in the reductions. As with CSBMs, perhaps Russia might be acceptable to the North in this role in the place of the U.S. Moscow has shown a concern to reduce instability in Northeast Asia, and might well be willing to assist in arms reduction talks between the two Koreas.

A related major role for the U.S. concerns the future of U.S. forces in South Korea, and the impact on those forces of an arms reduction treaty's verification regime. The question of a continued U.S. presence in Korea and, if so, at what level, should be addressed bilaterally between Seoul and Washington. If it is decided that a U.S. presence will remain, the details of how the treaty's verification regime will impact remaining U.S. forces, both during the reductions and afterwards, must also be addressed. For the best chance of success, the reduction negotiations should be restricted to a bilateral effort between the two Koreas. This would consequently place U.S. units in South Korea into a role as "stationed forces." Their role and participation during on-site inspections, for example, would need to be carefully worked out to avoid the potential for confusion and for compliance disputes between the North and the South.

BALLISTIC MISSILE/CHEMICAL AND BIOLOGICAL WEAPON (CBW) PROLIFERATION

The final source of instability to be examined impacts not only the Korean Peninsula, but other unstable regions as well. Activities comprising this instability include North Korea's indigenous production and sale of ballistic missiles -- primarily modified, extended range versions of the SCUD -- and research, production, and sale of chemical and biological weapons. To better understand this source of instability, it is necessary to examine each of these proliferation activities in more detail.

Ballistic Missile Proliferation

As detailed in Jane's Intelligence Review[11], North Korea is believed to be indigenously capable of ballistic missile body, warhead and propellent production, but its

[11] Joseph Bernudez, "Syria's Acquisition of North Korean SCUDs," Jane's Intelligence Review, Vol. 3, No. 6, June 1991, pp. 249-251.

abilities in guidance and control technology are thought to be low. North Korean production of SCUDs has required Chinese assistance that included the provision of technology for rocket design and production, metallurgy, and air frames to North Korea during the 1970s, and, in the early 1980s, for the North Korean SCUD upgrade program. North Korea is capable of producing SCUD-Bs, with a range of 300 km, at a rate of more than 50 per year, and has produced modified SCUD-Bs (or SCUD-PiPs) with improved accuracy and a range of 500 km.

A number of states are reported by the international media to have solicited or received aid from North Korea in acquiring ballistic missiles. Cuba is believed to have signed a contract with North Korea for SCUD missiles. Egypt is believed to be negotiating the purchase of North Korean SCUD-PiPs. Iran has reportedly received SCUD-PiP missile parts and utilized North Korean expertise to upgrade its Soviet-supplied SCUD-Bs, as well as improve its maintenance and production capabilities. During the Iran-Iraq war, North Korean and Iranian relations warmed considerably, and North Korea also reportedly provided Iran with other conventional armaments as well.

Syria is reported to have purchased an estimated 24 SCUD-PiPs and 20 launchers from North Korea in 1990. In February 1992, U.S. intelligence sources reportedly picked up and began tracking a North Korean cargo ship, the Dae Hung Ho, believed heading for Syria carrying advanced SCUD-PiP missiles and missile manufacturing equipment.[12] The ship docked on 9 March in the Iranian port of Bandar Abbas, and it is believed that the Iranian government agreed to transship the missiles to Syria.

There are also media indications that North Korea has aided Iraq in SCUD conversion, and supplied fuel tanks to extend their range. North Korea reportedly aided in the assembly of Iraq's 300 km SCUDs. North Korea and Libya have reportedly contracted to build a more recent modified version of the SCUD with a range of 1,000 km; Libya will supply the funding in exchange for some of the missiles and the technology.

While North Korea's allies (the former Soviet Union and China) have in the past provided much of the ballistic missile technology which North Korea has modified, Russia and China have more recently expressed concern over North Korea's proliferation of the technology. This probably directly attributable to North Korea's recent effort to develop a modified 1000 km SCUD, which will threaten significantly much more Chinese and Russia territory than the 500 km SCUD-PiP version.

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[12] John Lancaster, "Suspected SCUD Shipment Reaches Iran," The Washington Post, March 1, 1992, p. A11.

CBW Programs

- **Chemical Weapons**

According to a January 1989 article[13] in Jane's Defense Weekly, North Korea has the world's third largest chemical force, and a current chemical inventory that is known to include the Sarin (GB) family of nerve gases, Tabun (GA), Phosgene (CG), Adamsite (DM), the mustard gas family, and "blood agents" such as hydrogen cyanide.

The Korean People's Army (KPA) established its first chemical units in 1954, and during the first "Five Year Plan" (1957-1961), is believed to have begun to develop a chemical industry and chemical weapon production capability. Developing an indigenous capability apparently proved difficult, and in 1964, the North Koreans contracted with Japan to import small quantities of "agro-chemicals." In the 1970s, the North Koreans formalized trade agreements with Japan for further imports of these chemicals, as well as significant amounts of industrial chemicals, and by the 1980s the number of chemical imports from Japan increased dramatically. The Soviet Union and the People's Republic of China reportedly provided North Korea with limited quantities of chemical agents following World War II and in the early 1970s, in addition to World War II chemical/biological technology and protective gear. The Soviets provided technical assistance and training as well. In the early 1980s, the North Koreans were believed to have begun to produce and deploy significant numbers of chemical munitions.

All KPA and reserve personnel are reported to receive training in chemical and biological warfare through lectures and practical exercises at least four times a year. Dedicated chemical personnel spend over half of their branch training time on reconnaissance and decontamination. Like the Soviets, the North Koreans train with weakened but real chemical agents. The KPA's chemical/biological force is estimated at 9,900 personnel, or 1.2% of the army's total strength. Corps-level assets reportedly include a chemical defense section within the corps headquarters, and a chemical defense battalion.

Less is certain about North Korea's export and/or sale of chemical weapons outside of Northeast Asia, but there are indications that such activity is underway and again Pyongyang has chosen unstable regimes as a client or as a partner in developmental activity. From what has been reported in the media, it is believed that North Korea has sold chemical warheads to Syria in the past, to accompany the previously mentioned sale of SCUD-PiPs, and has been involved in a CW technology exchange with Cuba.

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[13] Joseph Bermundez, "CW: North Korea's Growing Capabilities," Jane's Defense Weekly, January 14, 1992, p. 54.

- **Biological Weapons**[14]

Less in known about Pyongyang's activity concerning biological weapons. North Korea is believed to have begun research in biological warfare during the mid-1960s. The primary research facility is the National Defense Research Institute and Medical Academy (NDRIMA). North Korean scientists have reportedly focused on ten different strains of bacteria, including anthrax, cholera, bubonic plague, smallpox and yellow fever. North Korea may have had the capability for offensive use of biological weapons since the early 1980s, but their limited medical capabilities to protect KPA troops probably has made use of BW on the Korean Peninsula unlikely. They are also reported to be cooperating with Syria in a biological warfare development program.

- **CBW Delivery Systems**

The KPA is reported to possess chemical/biological munitions for SCUD B tactical missiles, FROG 5 rockets, gravity bombs, and artillery rounds larger than 107 mm.

Nonproliferation Efforts

Clearly other states in the Northeast Asian region, primarily Japan, Russia, and China, are strongly interested in nonproliferation efforts to address North Korea's missile and CBW indigenous development and deployment on the Korean Peninsula. The U.S. has a similar strong interest but also seeks to end North Korea's production and sale to other unstable regions, including in the Middle East and to Cuba. The major mechanisms to assist in these efforts are certain nonproliferation treaties and regimes that have been concluded specifically to constrain weapons of mass destruction. They provide an international framework for regional states to accept prohibitions on such weapons, and establish a basis for acting against States Parties that violate their treaty obligations. To address North Korea's missile and CBW proliferation activities, arguably the following needs to be accomplished:

-- Both North and South Korea need to accede to the Biological Weapons Convention (BWC) banning development, production, testing, acquisition, and retention of BW weapons. Presently the South has ratified the BWC and the North has acceded to the agreement but has not yet ratified it. Importantly, both Koreas must be required to become Parties to the BWC, to establish an equitable basis for mutual security from biological weapons on the Korean Peninsula.

-- Both Koreas should also become signatories to the Chemical Weapons Convention (CWC) as it is concluded. As States Parties, they would agree to banning development, production, acquisition, and use of chemical weapons, and would have to accept monitoring of Treaty provisions by an international inspectorate.

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[14] *Joseph Bermudez, "CW: North Korea's Growing Capabilities", p. 54*

-- North and South Korea should agree to adhere to the CW Export Control Regime (the Australia Group). In doing so, each would exercise control over the export of chemicals potentially useful in developing chemical weapons and prevent their export to certain countries of proliferation concern including Iran, Iraq, Syria, and Libya, North Korea's current customers for the sale of CW.

-- In addition to the Nuclear Suppliers Group Guidelines and the Zangger Group Guidelines, the Koreas should also agree to conform to the Missile Technology Central Regime (MTCR), which controls the export of missile technology and missile systems with ranges over 300 km, and prohibits the transfer of facilities and technology to their production. This could serve to constrain North Korea's export of SCUDs to Middle Eastern clients. The MTCR lacks, however, an international framework banning missile systems with ranges in excess of 300 km and this omission would still allow North Korea to retain its modified, longer-range SCUDs and pose a threat to the Northeast Asian region. To foreclose this, both Koreas should also agree to ban the possession, development, production, acquisition, or transfer of ground-launched missiles with ranges greater than 300 km. In the event of such an agreement, the North and South could work out a verification regime for the ban that would feature bilateral on-site inspection, such as is now being negotiated for both Korea's nuclear-related facilities under the Join Declaration for a Nuclear-Free Korean Peninsula.

Tools to Accomplish Non-Proliferation Goals

A major impediment to getting North Korea to adhere to the nonproliferation treaties and regimes detailed above concerns the role that ballistic missile and CBW sales play in the staggering North Korean economy. Simply put, these sales represent a significant "cash crop" for Pyongyang, and a primary source for foreign capital. Even if the North can be persuaded to cease its missile and CBW proliferation activities in other regions, it would still require strong economic support from a new source to compensate for the income loss and to avoid serious damage to its economy.

Whether North Korea would agree to cease its proliferation activity in other regions is unclear. Although it may be in Pyongyang's clear interest to cooperate on nonproliferation issues in its own backyard in Northeast Asia, there is no such motivation to act responsibly in another region such as the Middle East. North Korea has enjoyed the reputation it has earned for cooperating with other unstable regimes like Syria, Iraq, Iran, and Libya. Pyongyang is arguably proud that it has the technology to indigenously develop and supply its Middle Eastern clients with weapon systems--ballistic missiles and CBW systems--that the others cannot provide on their own. Reluctance to lose this status and reputation will also conflict with any effort to persuade Pyongyang to agree to cease its proliferation activities.

In the face of these two present motivations, loss of a significant source of foreign currency and loss of international reputation and status, it is necessary to examine the general tools that the U.S. and its allies have to convince and motivate North Korea to agree to adhere to the non-proliferation treaties and agreements detailed above. They include the following (in increasing order of magnitude):

- **Exerting increased political, economic, and media pressure on North Korea** to cease its missile and CBW proliferation activities. It seems likely that the U.S. could enlist strong support from Russia and Japan in such efforts due to the threat that these North Korean proliferation activities pose to the Northeast Asian region. China, particularly when faced with the growing ranges of North Korea's modified SCUDs, may be more willing to join in such efforts than they appear to with regard to the North's nuclear proliferation efforts. To date, however, Pyongyang has successfully ignored significant U.S. efforts to exert such pressure. The most recent example of this involved the February shipment of SCUDs to the Middle East on the Dae Hung Ho, detailed earlier in this section. Despite U.S. protests, media attacks, and threats to stop the ship, the North still delivered the cargo of missiles. For future attempts to be more successful, a fully coordinated, intensive effort must be carried out both by the U.S. and its allies listed above. Also for these pressure tactics to be successful, they will arguably need to include an offer of an economic "carrot" to supplant the income lost by North Korea for agreeing to cease such proliferation activities. Japan could play an especially effective role in supplying such a "carrot" for the North.

- **Conducting a multinational conference of regional players** to address missile and CBW proliferation in Northeast Asia. As with nuclear nonproliferation efforts, the likely invitees should include North Korea, the U.S., South Korea, Japan, Russia, and China. The thrust of the conference could be to get the applicable nonproliferation treaties and export controls accepted and implemented for the Korean Peninsula. Again the challenge would be to conduct the conference without singularizing North Korea's proliferation activity. The drawback in holding such a conference would be that it could get into areas--such as ceasing the sale of all ballistic missiles to other states--that certain of the key participants in the conference, including Russia and China, might not wish to consider. Still many observers feel that a multinational conference, if carefully managed, might be effective in addressing this issue.

- **Imposing embargoes by suppliers.** As discussed above, North Korea's missile production efforts rely on outside assistance, including support believed to have come from China, in the areas of guidance and control technology. As noted, Japan is a major exporter of industrial chemicals key to Pyongyang. An embargo organized by the U.S. and involving both China and Japan may have a constraining effect on North Korea's missile and CBW proliferation. Such efforts would, however, have to continue for an extended period of time and given North Korean's national emphasis on self-sufficiency, it is uncertain how effective such an embargo might be.

- **Imposition of UN-sponsored or G-7 (plus Russia) sanctions and related embargoes.** The major drawback with this approach is the lack of a legal basis upon which to act. In the case of North Korea's nuclear proliferation activity, Pyongyang has acceded to the Nuclear Nonproliferation Treaty. The U.S. and others can tie its suspected nuclear proliferation activities to violation of that treaty and undertake action in response supported by international law. Unless and until Pyongyang accedes to international treaties such as the CWC and BWC and export control regimes such as MTCR, there is no treaty basis for the UN to act against North Korea's missile and CBW proliferation activities. Also North Korea is arguably only selling arms abroad, similar to the U.S., Russia, or China. Third World members of the UN may see efforts by U.S. and its allies to constrain North Korea's development and sale of missiles and CBW as primarily an effort by the developed world to eliminate a competitor. Western "plot" theories have developed in the UN over much less, and such feelings could impede the UN's ability to act. Attempts to get the G-7 and Russia to impose sanctions and embargoes could result in even more of a Third World backlash than trying to act within the UN.

- **Exerting military pressure/direct military action.** Clearly the U.S. attempted to exert military pressure to stop missile shipments on the Dae Hung Ho, and failed because it could seem find no legal basis upon which board the ship, and then lost surveillance coverage of it among the shipping traffic of the Persian Gulf. This failure could encourage Pyongyang to ignore similar military pressure in the future. Mounting direct military action suffers from a similar problem of standing. The U.S. and is allies would have to establish a convincing case that North Korea's missile and CBW proliferation activities posed a clear and present danger to regional and global security. Making the case would be difficult, given the underdeveloped world's suspicion of the West. It would also be crucial, however, to obtain necessary domestic U.S. support at a time when the reduction of U.S. military forces and focus of effort on domestic problems is the clear and overriding national agenda.

- **Third-party military action.** One other possibility often suggested is to have a state such as Israel remove the North Korean missile or CBW proliferation threat coming into the Middle East region through direct military action, such as sinking a delivery ship. This course of action has a potential advantage in that it would probably be effective. But the fallout of such an effort could also be significant. Israel, a U.S. ally although somewhat estranged, would have its reputation damaged again for hostile activity. The U.S. could also be condemned for having assisted, mostly likely due to suspicions of having provided intelligence support to such an operation, whether it did so or not. The possibility of a U.S. role in a direct third-party attack on North Korea could also result in North Korean-sponsored terrorist attacks against U.S. targets on opportunity, such as in South Korea.

SUMMARY

In the previous pages, four general sources of instability on the Korean Peninsula have been examined, including nuclear proliferation; political mistrust and suspicion; a conventional arms imbalance; and ballistic missile and chemical and biological weapon proliferation that affects not only Korea, but other instable regions as well. Nonproliferation efforts to address these sources have also been specifically discussed, including (1) efforts necessary to ensure that the joint agreement between the Koreas to denuclearize the Peninsula can be effectively verified; (2) confidence and security-building measures to reduce mistrust and suspicion; (3) use of the CFE Treaty as a general model for arms reduction of the two Korea's armed forces to a lower level of parity; and (4) efforts that may be used to address and resolve North Korea's ballistic missiles and CBW proliferation. There presently appears to be political will to undertake CSBMs that may improve the climate and serve as an ultimate catalyst for the arms reductions that both North and South Korea seem to realize are necessary. The two most difficult nonproliferation efforts involve ensuring that the agreement between the two Koreas to denuclearize the Peninsula is effectively verifiable, and that North Korea's missile and CBW development and sales cease. The most effective tools for these two efforts presently appear to be political, diplomatic, and particularly economic pressure, and convening a regional conference of major concerned states to address these issues. There are other, more imperative tools available to the U.S., but they also carry significant negative baggage if implemented, and would probably not be effective until the U.S. need to address these two sources of proliferation becomes more compelling.

Nonproliferation Aspects of Commercial Nuclear Fuel Cycles

P. Persiani
Argonne National Laboratory

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NON-PROLIFERATION ASPECTS OF COMMERCIAL NUCLEAR FUEL CYCLES

Paul J. Persiani
Engineering Physics Division
Argonne National Laboratory
9700 South Cass Avenue, Argonne, Illinois 60439
(708) 252-4870

Department of Energy – W-31-109-ENG-38

ABSTRACT

In the international non-proliferation regime of concern, the denatured uranium (i.e., low enrichments in ^{235}U or ^{233}U) fuel cycles should be assessed in terms of proliferation criteria. The study attempts to establish a technical basis for a comparative assessment of the proliferation potential among the denatured uranium, the plutonium-uranium, and the breeder fuel cycles. The international commercial fuel cycles were analyzed within the context of current technology for the potential to: divert and upgrade the quality of nuclear material via the construction and operation of clandestine-scale reprocessing facilities and low-technology electromagnetic enrichment facilities, such as calutrons. Eleven fuel cycles were analyzed to determine the number of calutron base-feed units (kg of heavy metal) contained in typical fuel assemblies for each of the cycles to produce a significant quantity of high enriched uranium (HEU) material within limited time periods. The study indicates that, for calutron specifications within current technology, the level of effort to enrich 3% $^{235}U/^{238}U$ to HEU fuel is a factor of 20 lower than the two-stage process with natural uranium feed; 16 to 20 calutrons and 6 to 8 fuel assemblies are required to produce a significant quantity of HEU in one year of operation. Consequently, non-proliferation concerns should be emphasized at the front-end of the fuel cycles involving uranium as well as at the back-end involving plutonium.

NON-PROLIFERATION ASPECTS OF COMMERCIAL NUCLEAR FUEL CYCLES

Paul J. Persiani
Engineering Physics Division
Argonne National Laboratory
9700 South Cass Avenue, Argonne, Illinois 60439
(708) 252-4870
Department of Energy – W-31-109-ENG-38

In the international non-proliferation regime of concern, the denatured uranium (i.e., low enrichments in ^{235}U or ^{233}U) fuel cycle systems should be assessed in the context of established proliferation criteria. The technical basis for the assumption that the denatured fueled reactor systems are less proliferation prone than the plutonium-uranium recycle system or the breeder fuel cycle has not been technically established. An assumption usually associated with the denatured fuel cycle systems is that the isotopic separation process adds a significant technical obstacle and a significant time delay in the detection of a covert or overt diversion. The level of effort to enrich uranium and the time to produce a significant quantity of nuclear material then become, in part, measures of proliferation resistance.

It is to address these proliferation criteria that Argonne initiated an investigation into the material flow in producing weapons-grade special nuclear material, SNM. The results of the analysis showed that a potential proliferation path, using calutrons for isotopic enrichment of low-enriched uranium, LEU, to highly enriched uranium, HEU, could be developed with mature technology by countries pursuing a clandestine weapons program. The analysis further indicated that a reasonable estimate in the time-differential between fuel cycle systems involving only chemical separation (plutonium) versus isotopic separation (uranium) may be a period of several months. Consequently, the time factor does not appear to be a significant measure of proliferation resistance when compared to the much longer time period spanning the actual diversion of the nuclear material from a fuel cycle to produce SNM in significant quantities. The proliferation potential profiles of the international commercial fuel cycle systems are to be measured against the capability to produce significant quantities of SNM, regardless of fuel cycle, and to construct and operate clandestine-scale processing facilities, such as aqueous chemical reprocessing for elemental separation, and/or enrichment facilities, such as calutrons for electromagnetic isotope separation.

The detailed considerations factored into this preliminary investigation are listed in the attached tables. Included in the tables are (1) estimates as to the level of effort in isotopic enrichment by calutrons to produce HEU material, starting with enrichment levels found in the commercial power generation fuel cycles; and (2) the inventory requirements of the fuel assemblies for each reference fuel cycle to yield significant quantities of HEU.

The analyses of calutron systems as summarized in the set of tables suggest that the proliferation concerns are to be addressed at the front-end of the fuel cycles for low-enrichment ^{235}U and ^{233}U systems. Table I lists the calutron specifications that can be developed within current technology. The capabilities include several levels of ^{238}U scatter into the ^{235}U or ^{233}U isotopic spread. Table II demonstrates that the calutron effort required to enrich 3% $^{235}U/^{238}U$ to weapons-grade quality is a factor of about 20 lower than the two-stage process with natural uranium as feed material. The analysis also showed that the calutron effort required to enrich $^{233}U/^{238}U$ reactor fuels, in a thorium cycle, to weapons-grade material may be lower by factors from 3 to 20 than the effort required to enrich 3% $^{235}U/^{238}U$ to a comparable weapons grade quality.

In order to evaluate the proliferation impact of clandestine mature technologies on the international commercial fuel cycles, a high level of knowledge is required in reactor design, analyses, and power operations, in the dynamics of isotopic separation and reprocessing plant operations, and in the synergistic interplay of these technologies within the nuclear fuel cycle. Eleven fuel cycles were analyzed to determine the number of calutron base-feed units (kg of heavy metal) contained in typical fuel assemblies to produce a significant quantity of HEU material within limited time periods. The set of Tables III and IV contains the number of fuel assemblies or equivalent enriched materials that would have to be diverted to obtain the fuel inventory requirements for producing a significant quantity of SNM. Referring to Table III, for the case of the pressurized water reactor (PWR) fuel cycle, two calutron base-feed units of 213 kg of heavy metal (HM) are contained in one fuel assembly of 460 kg HM. Table IV indicates that, on the basis of a one year calutron operation, about 16 to 20 calutrons (determined by the number of base-feed units) and 6 to 8 fuel assemblies of about 3% ^{235}U enrichment could produce a significant quantity of HEU. The study shows that non-proliferation concerns should be emphasized at the front-end of fuel cycles involving uranium, as well as at the back-end involving plutonium.

Table I. Electromagnetic Separation of Uranium Isotopes

Feed Enrichment, %	^{235}U Product Enrichment, %		^{233}U Product Enrichment, %		
	^{238}U Scatter[a]		^{238}U Scatter[a]		
	0.01	0.02	0.001	0.002	0.005
0.7	41	26	–	–	–
3	76	61	97	94	86
5	84	72	98	96	91
10	92	85	99	98	96
20	96	93	99+	99	98

[a] ^{238}U Scatter into ^{235}U and ^{233}U Peak, as a fraction of ^{238}U.

Table II. Electromagnetic Isotope Separation Product and Feed Inventory Requirements for a Significant Quantity of SNM

^{238}U Scatter: 0.01 ^{235}U, 0.005 ^{233}U
Ion Source: 400 mA

Separation Stages	Feed Enrichment, %	Fissile Product Enrichment, %	Uranium Product[a] Output, kg/yr	No. of Uranium Feed Base Units (213 kg/yr)
^{235}U				
1	0.7	41	0.54	394
2	41	99	13.12	1
^{235}U				
1	3	76	1.27	18
1	20	96	6.7	3
^{233}U				
1	3	86	1.10	7
1	5	91	1.75	4
1	10	96	3.33	2
1	20	98	6.43	1

[a] Ion Source Efficiency 15%: 100 mA, 8 kg uranium product, 53 kg uranium feed inventory; 400 mA, 32 kg uranium product, 213 kg uranium feed inventory.

Table III. Nominal Uranium, Plutonium, and Thorium Content in Typical Current Reactor Fuel Assembly Designs for LWRs

Fuel Cycle	Uranium		Pu/U Recycle	$^{233}U/U/Th$
Enrichment	2.9% $^{235}U/U$		2.3% $^{235}U/HM$ 0.8% Pu/HM	3.0% $^{233}U/HM$ 0.2% $^{235}U/HM$ (12% $^{233}U/U$)
	PWR	BWR		
Total HM (kg)	460	188	460	460(130 U)[a]
Charge (kg)				
235U	13.5	5.5	10.6	0.9
233U	–	–	–	13.8
Pu	–	–	3.7	–
Discharge (kg)				
235U	3.5	1.6	3.0	0.9
233U	–	–	–	8.4(7.3%/U)[b]
Pu	4.0	1.5	3.7	1.1

[a](kg) uranium in fuel assembly.
[b]Percent ^{233}U in uranium.

Table IV. Minimum Number of PWR Fuel Assemblies to Supply the Uranium Fuel Inventory Requirement for Minimum Critical Mass

Fuel Cycle	Uranium		Pu/U Recycle		$^{233}U/U/Th$	
Enrichment	2.9% $^{235}U/U$		2.3% $^{235}U/HM$ 0.8% Pu/HM		3.0% $^{233}U/HM$ 0.2% $^{235}U/HM$ (12% $^{233}U/U$)	
Total HM (kg)	460		460		460(130 U)	
	^{235}U	Pu	^{235}U	Pu	^{233}U	Pu
Reactor Input						
Isotope Separation	8		8		3	
Chemical Separation		–		2		–
Reactor Output						
Isotope Separation	–		–		5	
Chemical Separation		2		2		6-7

Global Measures and Constraints: Making Headway in the Middle East

J. Smith
Science Applications International Corporation

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PURPOSE

- TO CONSIDER SOME GLOBAL INITIATIVES THAT COULD FOSTER A ROLL-BACK OF NUCLEAR PROGRAMS IN THE MIDDLE EAST

AGENDA

- OVERVIEW OF CURRENT SITUATION
- CONSIDER TYPES OF GLOBAL INITIATIVES
- INVESTIGATE SOME SPECIFIC GLOBAL INITIATIVES THAT COULD HAVE A POSITIVE SPILLOVER EFFECT ON NON-PROLIFERATION EFFORTS IN THE MIDDLE EAST
- CONCLUSION

NUCLEAR PROLIFERATION IN THE MIDDLE EAST/PERSIAN GULF: OVERVIEW OF CURRENT SITUATION

- NUCLEAR EFFORTS OF IRAQ DISCLOSED IN THE WAKE OF THE GULF WAR
- ISRAELI PROGRAM IS WIDELY BELIEVED TO HAVE YIELDED A NOT INCONSEQUENTIAL NUCLEAR FORCE
- INTERNATIONAL CONCERNS HAVE INCREASED CONCERNING THE NATURE OF IRAN'S NUCLEAR AMBITIONS
- ALGERIA AND SYRIA ALSO HAVE MOUNTED NUCLEAR PROGRAMS THAT HAVE RAISED SOME SUSPICIONS
- LONGSTANDING CONCERNS REGARDING LIBYA'S ULTIMATE INTENTIONS IN NUCLEAR ARENA
- STRATEGIC LINK PERCEIVED BETWEEN NUCLEAR, CHEMICAL, AND CONVENTIONAL ARMAMENT

SETTING THE CONTEXT: INTERNATIONAL INITIATIVES

- UN SECURITY COUNCIL RESOLUTION 687 (4/91)
  - CENTERED ON IRAQ
  - SIGNALLED THAT ISRAEL'S NUCLEAR WEAPONS MAY NO LONGER BE PROTECTED FROM NON-PROLIFERATION PRESSURES
- MIDDLE EAST ARMS CONTROL INITIATIVE BY PRESIDENT BUSH (5/91) ENVISIONED
  - ELIMINATION OF MISSILES
  - WEAPONS-GRADE NUCLEAR MATERIALS BAN; EVENTUAL NPT ACCESSION
  - WORLD-WIDE PROHIBITION OF CHEMICAL WEAPON USE
  - RESTRAINT IN THE SUPPLY OF WEAPONS TO THE REGION
- IAEA GENERAL CONFERENCE DRAFT RESOLUTION ON SPECIAL MIDDLE EASTERN SAFEGUARDS REGIME (9/91)
  - MODEL SAFEGUARDS AGREEMENT WILL BE PREPARED BY IAEA SECRETARIAT
  - AGREEMENT WILL TAKE INTO ACCOUNT THE VIEWS OF THE STATES IN THE REGION
  - TO BE SUBMITTED TO THE BOARD OF GOVERNORS AND TO THE GENERAL CONFERENCE AT ITS REGULAR SESSION IN 1992

CONTROLLING THE SPREAD OF NUCLEAR WEAPONS IN THE MIDDLE EAST: GETTING FROM HERE TO THERE

- AFOREMENTIONED ACTIVITIES COULD CERTAINLY QUALIFY AS "GLOBAL INITIATIVES"
- THERE ARE MANY POTENTIAL IMPEDIMENTS TO THEIR FULL IMPLEMENTATION
  - SECURITY CONCERNS
  - POLITICAL AND DIPLOMATIC DISAGREEMENTS BETWEEN ISRAEL AND ARAB STATES
  - POTENTIAL PERCEPTIONS OF UNWARRANTED OUTSIDE INTERFERENCE
- OTHER GLOBAL INITIATIVES MAY HOLD MORE IMMEDIATE PROMISE

TYPES OF GLOBAL INITIATIVES

- EXTRA-REGIONAL EFFORTS UNDERTAKEN SPECIFICALLY TO CAP PROLIFERATION IN THE MIDDLE EAST
  - DENIAL (I.E., SUPPLIER REGIMES)
  - PROSELYTISM
  - COERCION

- ALTERNATIVE: TREND-SETTING ACTIVITY BY STATES OUTSIDE THE REGION, ESPECIALLY THE UNITED STATES
  - GLOBAL APPLICABILITY
  - PROVIDE MIDDLE EASTERN STATES WITH AN OPPORTUNITY FOR NUCLEAR CONFIDENCE-BUILDING IN INTERNATIONAL CONTEXT
  - IN SOME CASES, ENCOURAGE STEPS IN AREAS THAT MAY BE VIEWED BY STATES IN THE REGION AS LESS THAN VITAL TO REGIONAL SECURITY CONCERNS
  - POTENTIAL PROBLEM: SUCH INITIATIVES MAY REQUIRE FUNDAMENTAL CHANGES IN US STRATEGIC THOUGHT

REPORTING REQUIREMENT ON NATURAL URANIUM AND YELLOWCAKE (I)

- POST-IRAQ ASSESSMENTS HAVE RAISED ISSUE OF LOWERING THE STARTING POINT FOR SAFEGUARDS -- POTENTIALLY VERY COSTLY
- EQUALLY ATTRACTIVE OPTION WOULD BE TO INTRODUCE A REPORTING REQUIREMENT ON THOSE FUEL CYCLE ACTIVITIES THAT CURRENTLY DO NOT REQUIRE SAFEGUARDS
  - REPORTING ON PRODUCTION LEVELS AND PROJECTED USE OF NATURAL URANIUM AND YELLOWCAKE
  - LEAVING OPEN THE POSSIBILITY OF IAEA INSPECTIONS TO VERIFY REPORTS
- COULD BE UNDERTAKEN BY THE IAEA OUTSIDE THE FRAMEWORK OF THE NUCLEAR NON-PROLIFERATION TREATY TO MAXIMIZE ADHERENCE

REPORTING REQUIREMENT ON NATURAL URANIUM AND YELLOWCAKE (II)

- POTENTIAL IMPACT
  - MAY BE AN IMPORTANT SYMBOLIC STEP FOR ISRAEL, INCREASING TRANSPARENCY IN AN AREA OF NUCLEAR PROGRAM THAT MAY NOT BE DEEMED CRITICAL TO NATIONAL SECURITY
  - COULD INCREASE TRANSPARENCY AND, HENCE, CONFIDENCE VIS-A-VIS SUCH STATES AS IRAN AND ALGERIA
  - AVAILABILITY OF SUCH DATA, AND FREEDOM TO VERIFY IT, COULD HAVE PROVIDED A RED FLAG IN IRAQ BEFORE THE GULF WAR

DELEGITIMIZE THE PRODUCTION AND USE OF WEAPONS-GRADE MATERIALS (I)

- CONCERNS RELATED TO PRESENCE OF HIGHLY-ENRICHED URANIUM FUEL IN IRAQ PRIOR TO GULF WAR
  - POINTS TO THE NEGATIVE IMPACT THAT SUCH MATERIALS CAN HAVE ON REGIONAL AND INTERNATIONAL CONFIDENCE LEVELS
  - SIMILAR CONCERNS PROMPTED BY PERCEIVED PLUTONIUM PLANS IN IRAQ (1981) AND NORTH KOREA
- MEASURES THAT WOULD DELEGITIMIZE PRODUCTION AND USE OF WEAPONS-GRADE MATERIALS COULD
  - PROVIDE IMPORTANT CONFIDENCE-BUILDING MEASURES
  - REDUCE THE RISKS OF DIVERSION FROM CIVIL TO WEAPONS USE
  - REDUCE PRESSURES ON NEIGHBORING STATES TO ENGAGE IN COSTLY NUCLEAR COMPETITION

DELEGITIMIZE THE PRODUCTION AND USE OF WEAPONS-GRADE MATERIALS (II)

- TO BE A TRULY GLOBAL INITIATIVE, AND TO MINIMIZE INTERNATIONAL CRITICISM, UNITED STATES AND OTHER NUCLEAR WEAPON STATES WOULD NEED TO BE PREPARED TO
  - REDUCE HOLDINGS OF WEAPONS-GRADE MATERIALS
  - ADOPT OVERT RESTRICTIONS ON PRODUCTION CAPACITY
- WOULD FACE OPPOSITION FROM STATES SUCH AS JAPAN
- COULD CONSTRAIN OPTIONS FOR DESTROYING FISSILE MATERIAL REMOVED FROM WEAPONS FROM FORMER SOVIET STOCKPILE

DELEGITIMIZE THE PRODUCTION AND USE OF WEAPONS-GRADE MATERIALS (III)

- PROMOTE CREATION OF ZONES WITHIN WHICH REPROCESSING PLANTS, ENRICHMENT PLANTS, POSSESSION AND USE OF WEAPONS-GRADE MATERIALS WOULD BE BANNED
  - SPECIAL EMPHASIS ON REGIONS WHICH TEND TOWARD CONFLICT OR HIGH TENSION
  - INTERIM STEP COULD BE TO ACCEPT VERIFIABLE LIMITS ON URANIUM ENRICHMENT LEVELS
  - THE UNITED STATES AND REPUBLICS OF THE FORMER SOVIET UNION COULD LEAD THE WAY, TAKING STEPS THAT WOULD CULMINATE IN A FORMAL FISSILE MATERIAL PRODUCTION CUT-OFF

- SAFEGUARDED INTERNATIONAL PLUTONIUM STORAGE
  - UNITED STATES AND RUSSIA COULD SUBMIT PLUTONIUM REMOVED FROM DISMANTLED TACTICAL WARHEADS
  - DE FACTO NUCLEAR WEAPON STATES MIGHT BE ENCOURAGED TO DRAWDOWN THEIR OWN PLUTONIUM STOCKPILES IN A SIMILAR MANNER, WITH NO QUESTIONS ASKED WHEN THE MATERIAL WOULD BE DEPOSITED TO STORAGE
  - STATES COULD TENDER PLUTONIUM-BEARING SPENT FUEL FOR REPROCESSING AT INTERNATIONALLY-MONITORED PLANTS
    - PLUTONIUM TO BE STORED IN INTERNATIONAL FACILITY
    - FUEL RETURNED FOR RE-USE, IF DESIRED

TESTING CONSTRAINTS (I)

- NATIONAL SECURITY RATIONALE FOR CONTINUED NUCLEAR TESTING MAY FADE IN CURRENT STRATEGIC ENVIRONMENT
- UNDERTAKE SPECIFIC & SUBSTANTIAL COMMITMENT TO REDUCE NUCLEAR TESTS

TESTING CONSTRAINTS (II)

- **BENEFITS**
  - HINDER ANY MOVEMENT IN FSU TO COMMERCIALIZE PEACEFUL NUCLEAR EXPLOSIONS
  - REINFORCE FIRST OPEN INDICATIONS OF RESTRAINT IN FRENCH NUCLEAR PROGRAM
  - CREATE A GLOBAL CONTEXT WITHIN WHICH STATES IN THE MIDDLE EAST COULD
    - REINFORCE NPT COMMITMENTS BY AN EXPLICIT PLEDGE TO FOREGO TESTING
    - MAKE AN INITIAL COMMITMENT NOT TO TEST, IN THE CASE OF NPT NON-SIGNATORIES

- **COMPLICATION**
  - STRICTER TESTING LIMITS COULD CONSTRAIN DISPOSAL OPTIONS FOR NUCLEAR WARHEADS
  - SUCH CONSTRAINTS ARGUABLY ALREADY EXIST IN THE FORM OF POLITICAL OPPOSITION TO RESUMED TESTING IN RUSSIA

CONCLUSION (I)

- ELIMINATION OF WEAPONS OF MASS DESTRUCTION IN MIDDLE EAST WITHIN CONTEXT OF ARMS CONTROL
  - MAY BE POSSIBLE
  - PROGRESS MAY BE EXCRUCIATINGLY SLOW
- MORE IMMEDIATE ALTERNATIVE MAY BE TO UNDERTAKE NEW INITIATIVES THAT
  - CAPITALIZE ON A LESSON OF THE IRAQI EXPERIENCE
  - BUILD ON PROGRESS IN EAST-WEST REDUCTIONS IN TENSION AND NUCLEAR ARMS

CONCLUSION (II)

- o RESULTS OF SUCH EFFORTS
  - BUTTRESS GLOBAL NORMS
  - REDUCE PERCEPTION THAT NON-PROLIFERATION REGIME PERPETUATES DICHOTOMY BETWEEN HAVES AND HAVE-NOTS
  - CREATE OPPORTUNITY TO BUILD CONFIDENCE IN MIDDLE EAST
    - = FACILITATE ACTUAL REDUCTIONS
    - = INCREASE EXPERIENCE WITH INTERNATIONAL MONITORING
- o CLEAR THAT INITIATIVES SUCH AS THOSE DISCUSSED HERE WILL BE HARD TO COME BY
  - SIGNIFICANT BENEFITS LIKELY TO RESULT, HOWEVER
  - EXPERIENCE TO DATE IN EFFECTING SUCH CHANGES SUBSTANTIATES THIS NOTION

A Systems Approach to Dealing with Proliferation in a Changing World

M. Wheeler
System Planning Corporation

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Introduction

Proliferation in all its dimensions has emerged as a -- some have suggested the -- major challenge facing security planners today. Policy discussions in Washington during the past several months have reflected the following sorts of themes:

- In the April 1992 candidates' forum in *Arms Control Today*, President Bush responded to a set of questions on arms control and national security. "I have given the highest priority," the President said, "to reducing the danger of nuclear proliferation." He also described the importance of other policy measures to combat proliferation, consistent with the fact that in November 1990 he had issued Executive Order 12735 which states: "proliferation of chemical and biological weapons constitutes an unusual and extraordinary threat to the national security and foreign policy of the United States and [I] hereby declare a national emergency to deal with that threat."

- In the message which opened his February 1992 annual *Report to the President and the Congress*, Secretary of Defense Dick Cheney highlighted proliferation problems. "Today, some 15 nations have ballistic missiles -- in less than a decade, as many as 20 countries may possess these systems. Nuclear, chemical, and biological weapons, as well as advanced conventional systems, can make distant conflicts a worldwide concern."

- In an interview published in the *Christian Science Monitor* in May 1992, Secretary of Sate James Baker was quoted as saying: "[Nonconventional weapons] proliferation is a major problem, maybe one oɪ the two most pressing problems in the world."

These concerns are not limited to the Bush Administration.

- Congressmen Les Aspin and William Dickinson concluded in their recently published report on *Defense for a New Era: Lessons of the Persian Gulf War* that "the global proliferation of ballistic missile technology and weapons of mass destruction has become one of the most immediate and dangerous threats to U.S. national security in the post Cold War era."

• And at the first Security Council summit convened at the levels of heads of government in early 1992, the closing communique called on all UN members "to prevent the proliferation in all its aspects of weapons of mass destruction [and] to avoid excessive and destabilizing accumulations and transfers of arms."

Proliferation means different things to different people. To begin to appreciate the extent and scope of the types of problems associated with proliferation, consider some of the current issues facing American policymakers:

• Can the Nuclear Non-Proliferation Treaty (NPT) weather the critical 1995 revision conference unless the United States ceases nuclear testing and renounces first use of nuclear weapons?

• Does quick conclusion of the Chemical Weapons (CW) Convention require further compromise and adjustment on the question of challenge inspections?

• Should the Biological Weapons (BW) Convention be amended to provide a verification regime, and if so, what verification measures appear to have even a reasonable prospect of effectiveness?

• How can weapons of mass destruction best be dealt with in regional contexts, especially in the Middle East, South Asia, and Northeast Asia?

• Will trade sanctions imposed against the Russian space trading company Glavkosmos and the Indian Space Research Organization, in the context of the Missile Technology Control Regime (MTCR), undercut the wider Western security agenda toward Russia and India?

• Is the MTCR discriminatory (and perhaps ineffective) because it excludes long-range strike aircraft?

• What can be done to keep excess advanced general-purpose armaments (such as stockpiles of modern main battle tanks) which are the residue of the Cold War from proliferating widely?

These are not questions to be dealt with in isolation. They are part of the larger public debate on security requirements already underway in the United States and in most industrialized nations around the world.

Proliferation and the U.S. security agenda

Non-proliferation policy in the United States in fact is a loose collection of separate policies addressing arms control, arms transfers, export controls, issues of global diplomacy, regional strategies, bilateral relations, and related matters. Where proliferation once was a problem which could be described with large brush strokes, that no longer is true. The proliferation challenge is more dangerous and diverse than ever has been the case in the postwar era.

The time is ripe to step back from the specific issues and systematically think through proliferation, noting patterns and interconnections among the constituent parts. It also is time to explore whether an organized set of resources and procedures united and regulated by interaction and interdependence to accomplish a common function is an appropriate response to security challenges posed by the proliferation of arms.

This paper opened with the suggestion that proliferation could be thought of as a threat to U.S. security. In fact, proliferation is not so much a treat as an enabling condition which contributes to threats. It is conventional wisdom that weapons of mass destruction in the hands of aggressors pose an obvious danger to international peace and security. Emerging arsenals of advanced conventional weaponry supplement this more traditional view.

Like most complex social problems, proliferation is composed of factual and subjective components. Assessing some of the constituent elements reveals the following.

First, there are well-known difficulties in characterizing the underlying motives for national armaments programs. International relations are conducted in an intricate social milieu where objectives, resentments, and personalities brew into widely varying conceptions of national interest and goals. Nations maintain militaries for a host of reasons, and their reasons for going to war are varied. It is hard to find a war where political leaders believe they are in the wrong, and where their populations view their nation's actions as aggression. And if the "aggressor/non-aggressor" distinction poses difficulties in explicating international norms, those difficulties are compounded even further when one attempts to contrast "offensive" ambitions with "defensive" ones as the basis for norms on what armament programs are acceptable internationally.

Then there are the realities of a world divided into nations with widely divergent levels of wealth and power. These realities give rise to arguments of equity, especially where some nations possess weapons of mass destruction and others do not. The sensitivities of political elites in many non-nuclear-weapons states are expressed by K. Subrahmanyam, an Indian opinion leader who chaired the U.N. Study Group on Nuclear Deterrence and who publishes and speaks widely on the subject, when he says: "If arms control is to be meaningful in the future system, it has to be universally applicable and nondiscriminatory. Double standards, such as those that allow some nations and not others to possess weapons of mass destruction, are a sure way to promote covert weapon proliferation and ambiguous strategies."[1]

The dilemma is even more pronounced for conventional weapons. The international community has failed to agree in any coherent or sustainable fashion on what *global* or *regional/subregional* military balances are "stabilizing," to use a commonly accepted term. Without even minimal standards for what constitutes a baseline notion of legitimate (conventional) military balances, establishing norms for arms transfers is extraordinarily difficult. In a paper prepared shortly before the 1978 United Nations Special Session on Disarmament, one long-time student of the problem summarized the dilemma as follows:

> Sound judgments about arms transfers are difficult to reach. Unlike the spread of nuclear weapons, there is no global consensus that the transfer of conventional weapons is, in every instance, a detriment to the interest of international peace or security. There are no "simple truths" to serve as guidelines for policymakers. Prospective arms transfers may or may not be a stabilizing factor within a region; they may or may not promote the broader foreign policy objectives of the suppliers

1. K. Subrahmanyam, "Some Nations More Equal than Others," *The Bulletin of the Atomic Scientists* (June 1991), p. 21.

or the recipients; they may or may not have economic or technological benefits for the seller or the purchaser. Each arms transfer decision has distinct and unique features.[2]

Another aspect of the problem is the challenge of maintaining a composite policy over a long period of time. This is not a new dilemma. Consider, for instance, the hand-held crossbow -- one of the major weapons innovations of the Middle Ages.

The crossbow challenged the central institution of medieval warfare (and arguably of the medieval social order), the armored warrior class. The destabilizing effects of this weapon were sufficiently recognized by 1139 for the Pope to issue an edict banning the crossbow as an instrument of warfare. Given the authority of the Church at the time, a medieval papal edict carried significant authority.

However, as is the case today, opposing objectives can arise which dilute the force of anti-proliferation efforts. For the crossbow, the crusades served that function. The papal edict was modified to permit Christians fighting in the crusades to use crossbows against their adversaries.

The practical effects of the papal edict eroded over several decades. It is ironic that one of the great battle commanders of the Middle Ages, Richard Cour de Lion, survived the dangers of the Third Crusade only to die of gangrene from a wound inflicted in France in 1199 by a crossbow bolt.

The crossbow allowed the common foot soldier, even a poorly trained one, to deliver shock power from a distance against armored knights on horseback. The crossbow triggered an arms race. Countermeasures such as heavy plate armor in place of mail armor evolved, and in turn, crossbows became more lethal. By the end of the fourteenth century, the steel crossbow was the most powerful weapon on the battlefield. It retained this preeminent position until the mid-fifteenth century when its shock power was replaced by applying a different physical phenomenon to essentially the same military task of shock power at a distance. With the advent of gunpowder, the hand gun and artillery eventually became weapons of

2. Andrew J. Pierre, "International Restraints on Conventional Arms Transfers," in Jane M.O. Sharp, editor, *Opportunities for Disarmament: A Preview of the 1978 United Nations Special Session on Disarmament* (Carnegie Endowment for International Peace, 1978), pp. 47-49.

choice, and use of the crossbow gradually moved to the margins of warfare.

What does the crossbow tell us about proliferation?

Proliferation of a weapons system does not have to be rapid to be dangerously destabilizing, nor is it restricted to finished weapons system deployed within a short time. Rather, proliferation can begin slowly, spread steadily, and modify itself as it proceeds.

Even when a weapons system is seen as destabilizing, multiple interests inevitably clash in the debate over whether or it should be controlled or banned. The non-proliferation regime -- that is to say, the agreed rules and procedures -- may prove insufficiently resilient as old interests shift and new ones arise.

Weapons technologies do not stand still. Deployments trigger countermeasures. New technologies overtake old ones.

What the preceding discussion suggests is that the proliferation problem can be thought of as an interaction among practical policy choices and more abstract concepts such as authority, equity, and sovereignty. The proliferation problem can be stated as follows:

- identifying a weapon (or class of weapons) whose proliferation is destabilizing (with the related difficulty of achieving consensus on what "destabilizing" means);

- achieving consensus among all potential suppliers that proliferation of the weapon is destabilizing;

- achieving consensus among all potential proliferants that their security does not require them to acquire the weapon;

- balancing the equities of all those involved;

- for those who can't be convinced, preventing (or at least inhibiting) proliferation of the weapon;

- sustaining a non-proliferation regime over time, especially in the face of conflicting objectives and demands, frequent changes of government, and advances in military technology;

• enforcing compliance;

• establishing adequate safeguards (whose application does not tend to undercut the non-proliferation regime) against the danger that non-proliferation activities will fail.

The value of this sort of framework becomes clearer when examining the three general categories of weapons proliferation which are part of the policy debate: (1) weapons of mass destruction, (2) advanced delivery systems for weapons of mass destruction, and (3) other types of weapons.

Weapons of mass destruction

Weapons of mass destruction (sometimes also called special or unconventional weapons) fall into three currently-recognized categories: nuclear, biological, and chemical.

The United States acquired nuclear weapons through an elaborate set of circumstances during a time of extreme national emergency. Once having acquired those weapons, American leaders used them to end the Second World War. After 1945, no way was found to give up nuclear weapons unilaterally without leaving the nation seriously threatened, especially given the widespread peaceful uses of atomic energy and the knowledge that atomic bombs can be built. To repeat the truism, the genie could not be put back into its bottle.

Early attempts to set up a comprehensive international control regime of the sort proposed in the Baruch plan were sincere but almost certainly unattainable in the complex political environment following the war. By the time the Cold War ended some five decades later, the two superpowers -- the United States and the USSR -- had agreed in a series of treaties and cooperative gestures to reduce and further limit their nuclear arsenals. That process of bilateral nuclear arms control between the United States and the successors to the USSR -- especially the Russian Federation -- is continuing.

Neither Russia nor the U.S. sees nuclear abolition as an attainable goal for the indefinite future. Nor do France, the United Kingdom, China, and -- presumably -- the other states thought to either have or be close to having a nuclear weapons capability such as Israel, India, or Pakistan. It is far from clear that Iraq's program to acquire nuclear weapons has been successfully derailed over the long term, and the issue of a North Korean nuclear bomb remains high on all agendas.

Today it is easier for a fledgling nuclear-weapons state to develop nuclear weapons than was the case at any time in the postwar era.[3] That is true despite the existence of an important and fairly robust nuclear non-proliferation regime. International regimes of this sort can best be thought of as a mix of rules and procedures embodied in treaties, U.N resolutions, supplier agreements, domestic legislation, and other institutional arrangements. The 1968 Nuclear Non-Proliferation Treaty (NPT) and the International Atomic Energy Agency (IAEA) system stand at the heart of the nuclear non-proliferation regime.

Despite obvious differences from nuclear weapons, biological weapons are dangerous in a way approaching the lethality of their nuclear counterparts. Primitive forms of biological warfare (e.g., placing diseased carcasses in water supplies of besieged cities) are as old as war itself. In this century, the international community has sought to ban biological weapons. The 1925 Geneva Protocol prohibited their first use -- a prohibition which was extended in 1972 in the Biological Weapons Convention to the development, production, and stockpiling of biological and toxin weapons.

These two treaties stand at the heart of the non-proliferation regime dealing with biological weapons. Assessing the soundness of this regime is is affected by several salient facts. First, there is no verification regime for the existing BW conventions. Second, there are what appear to be insurmountable problems (such as the small size, widespread availability, and dual-use nature of items involved in biological research) which have led many to believe that verification regimes cannot be developed for biological weapons. And third, one of the most dynamic areas of modern science resides in the biological sciences, especially molecular biology,

3. This conclusion was reached in two recent studies: the 1991 National Academy of Sciences study on *The Future of the U.S.-Soviet Nuclear Relationship*, and the more recent study that Tom Reed and I submitted to the Senate Armed Services Committee in January 1992, entitled *The Role of Nuclear Weapons in the New World Order.*

which suggests that there may be multiple, novel, and perhaps easily concealed paths for a nation intent on developing biological weapons of mass destruction. Seeking ways to strengthen the BW convention is high on many contemporary agendas.

Some have contended that biological, like chemical, weapons are the poor man's nuclear weapon. Chemical weapons have less of a claim to be weapons of mass destruction, but whatever the objective facts of chemical lethality, the psychological facts are overwhelming. Chemical weapons are seen by many nations as unconscionable weapons, and are deliberately linked by some as counters to nuclear postures.[4]

The 1925 Geneva Protocol also banned the first use of chemical weapons. The more comprehensive Chemical Weapons Convention, under negotiation now in one form or another for a number of years, proposes to ban the production and stockpiling, as well as the first or even retaliatory uses, of chemical weapons. Within the context of this wider convention, the United States and the USSR in 1990 signed a bilateral agreement to cease producing and to destroy their existing CW stockpiles. Boris Yeltsin has reaffirmed that agreement on the part of the Russian Federation, although he is seeking relief from the timetables arrived at earlier for destroying the chemical weapons arsenals of the former USSR.

Both the CW and the BW regimes permit defensive research. This is a vital safeguard in the absence of a comprehensive regime of reliable verification and non-hostile relations among potential proliferants of CW or BW.

Any systematic, cross-cutting review of the nuclear, biological, and chemical non-proliferation regimes demonstrates the intricate relationship among these unconventional weapons and the policies dealing with their development, production, stockpiling, and use.

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4. Adbel Monem Said Aly, a Senior Researcher at the Al-Ahram Center for Political and Strategic Studies in Cairo, points out: "During the Paris Conference on Chemical Weapons in January 1989, the Arab states supported multilateral efforts to impose a total ban on chemical weapons, but they asked that a future chemical weapons convention include effective security guarantees for its members, not only against the use or threat of use of chemical weapons but also against the use or threat of use of any weapon of mass destruction. Nuclear weapons states refused to link the ban on chemical weapons with the ban on nuclear weapons. This refusal has added to the suspicion of the Arab countries with regard to the credibility of such international regimes." "Quality vs. Quantity: The Arab Perspective of the Arms Race in the Middle East," in Shelley A. Stahl and Geoffrey Kemp, editors, *Arms Control and Weapons Proliferation in the Middle East and South Asia* (St. Martin's Press, 1992), pp. 70-71.

The major nuclear-weapons powers realize that unilateral disarmament is a utopian fantasy. Reductions of nuclear stockpiles to stabilizing levels is the more realistic goal. The largest nuclear powers -- the United States and Russia -- appear willing to reduce their nuclear arsenals to levels far below the Cold War balance, and to place other controls on the arsenals.[5]

Non-nuclear-weapon states that feel threatened by nuclear weapons counter that their right to pursue nuclear weapons, or to acquire biological or chemical weapons to offset nuclear weapons, is justified by the insistence of nuclear-weapons states to retain their weapons of mass destruction. This is an argument that will not be resolved easily or soon.

Within that conundrum, the challenge to the world community is to reach a point where an accepted norm is established for all weapons of mass destruction -- a norm which is widely perceived to serve all nations' security interests. That norm should involve at least three elements: (1) for nuclear-weapons states, responsible national stewardship of existing nuclear arsenals at lower, safer, more stabilizing levels; (3) for non-nuclear weapons states, prevention of further destabilizing proliferation of nuclear weapons; and (3) for all states, global bans on chemical and biological weapons, with a reasonable degree of assurance that compliance is taking place.

Advanced delivery systems

In the early 1980s, the Reagan administration began quietly studying the prospects of a regime to inhibit proliferation of advanced delivery systems for nuclear weapons. After consultations with its major trading partners, what emerged in April 1987 was the Missile Technology Control Regime (MTCR). By the start of 1992, the MTCR had expanded to 18 members.

5. When the USSR collapsed, Russia, Ukraine, Belarus, and Kazakhstan had nuclear weapons. Those successor states have engaged in complicated, on-again, off-again negotiations for the final disposition of the Soviet nuclear arsenal -- an activity which will take years to implement. For purpose of simplicity in this discussion, the paper will talk of the Russian arsenal instead of a Commonwealth arsenal or a mix of nuclear arsenals.

An obvious deficiency of the MTCR in its early years was the fact that the USSR and China were not members. The most widely proliferated ballistic missile in the world for the past two decades has been the Soviet Scud B and its numerous variants. This is the missile used so extensively during the Iran-Iraq and the Gulf wars.

Bilateral U.S.-Soviet talks on Soviet adherence to the MTCR commenced in 1988.[6] In one sense, the USSR was not the major problem by the time those talks commenced. Scud proliferation from the USSR took place largely in the 1970s. Subsequent proliferation has been driven largely by retransfers and external production over which the USSR had at best problematic control.

The Scud is a primitive system by contemporary standards. The Scud design is based upon the World War II V-2 rocket system. There are engineering and physics limits on how much can be done to modify a Scud B missile. the maximum range of modified single-stage Scuds appears to be in the vicinity of 1000 kilometers, and at that range, the accuracy of an already relatively inaccurate missile drops precipitously.

By the 1990s, the People's Republic of China has emerged as one of the largest exporter of military equipment in the Third World.[7] Diplomatic efforts to effectively constrain destabilizing arms sales by the Chinese continue. The Chinese authorities have consistently argued that a regime which restricts their sales of ballistic missiles while allowing Western sales of advanced strike aircraft is inequitable.[8]

The Chinese argument highlights the question of why constrain only the proliferation of ballistic missiles. Although policy focus has been on ballistic missile systems, in fact the MTCR sought to limit the spread of all

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6. The discussions with the Soviets involved a number of issues, not the least of which was the demand that the USSR be treated on an equal footing with Western partners of the United States. That theme was evident in Boris Yeltsin's 29 January 1992 televised address, where he discussed as part of his arms control agenda willingness by the Russian Federation to "in principle" join the international regime on non-proliferation of missiles and missile technology "as an equal participant." The continuing sources of tension, however, are demonstrated in Russia's refusal to rescind the agreement to sell Russian rocket engine technology to India for use in (and allegedly restricted to) the Indian civilian space program.
7. See Richard A. Bitzinger, *Chinese Arms Production and Sales in the Third World*, RAND N-3334-USDP (1991).
8. See John W. Lewis, Hua Di,.and Xue Litai, "Beijing's Defense Establishment: Solving the Arms-Export Enigma," *International Security* (Spring 1991).

missiles and unmanned air vehicles and delivery systems capable of carrying at least a 500 kilogram payload to at least 300 kilometers. The MTCR excluded manned strike aircraft. A recent study on this matter has proposed that the "United States should explore bringing export controls on ballistic missile and strike-aircraft systems and technologies more into balance."[9]

Regimes like the MTCR can slow the proliferation of weapons systems. They cannot prevent the spread of such systems to determined new proliferants, nor can they consistently block the improvement of systems in nations currently possessing existing missile systems.

Conventional weapons

Whereas there is considerable (although not universal) agreement on the rules and conventions to apply to proliferation of weapons of mass destruction, and some agreement on a regime for dealing with military missiles, norms for a non-proliferation regime are almost totally absent when it comes to conventional arms.

To the extent there is an accepted norm, it appears to derive from Article 2 of the United Nations Charter in which all members pledge "to give the United Nations every assistance in any action it takes in accordance with the present Charter, and... [to] refrain from giving assistance against which the United Nations is taking preventive or enforcement action." A case can be made that acceptance of this article "creates an indirect obligation on all governments that are members of the United Nations to establish standing mechanisms for the national regulation of their arms exports in order to be in a position to enforce mandatory UN arms embargoes."[10]

This norm relies upon mandatory arms embargoes imposed by the United Nations. Beyond the scenario-specific cases of mandatory UN arms embargoes, however, the only other primitive elements of a non-proliferation regime for conventional arms are emerging in the areas of transparency

9. *Assessing Ballistic Missile Proliferation and Its Control* (Center for International Security and Arms Control, Stanford University, November 1991), p. 10. The merits of the MTCR issues will not be explored in this paper. What to do to tighten the regime, how to more effectively deal with cruise missile proliferation, and whether to entertain some similar regime for strike aircraft are important policy questions.

10. Ian Anthony, editor, *Arms Export Regulations* (Oxford University Press, 1991), p. 1.

and of coordinated restraint by major arms suppliers.

Proposals to establish an international register describing the arms trade date to the League of Nations. In 1965, the United Nations discussed a draft resolution proposed by Malta, inviting the UN Committee on Disarmament to consider establishing a system within the United Nations to make public information concerning the transfer of arms between states. The proposal was rejected at the time, as were other proposals until -- after a study completed in 1991 by a team of government experts convened by the Secretary General -- the General Assembly voted to establish such a register. The establishment of the registry is underway.

As for coordinated restraint by major arms suppliers, Saddam Hussein's blatant aggression in the Gulf, and the subsequent united response by the international community, formed the backdrop for talks among major arms suppliers on limiting destabilizing flows of arms into the Middle East. Reports on these talks suggest modest progress thus far, for reasons of the sort discussed earlier in this paper.

Forging consensus on restricting conventional arms and technology transfers is a threefold challenge.

The first part of the challenge is at the national level. Achieving domestic agreement on what arms transfers to permit or restrict as a matter of national laws and policy often is difficult. Recurring disagreements in the United States on the propriety of arms sales to Saudi Arabia, for instance, illustrate the sorts of domestic difficulties involved.

The second part of the challenge is to forge consensus among like-minded nations that technologies or weapons should not be transferred. The premier regime for addressing conventional armament technologies during the Cold War was the Coordinating Committee on Multilateral Export Controls (COCOM). That regime has changed rapidly for obvious reasons, and the 1992 Camp David declaration that Russia and the United States do not regard each other as potential adversaries but will move to a relationship characterized by friendship and partnership founded on mutual trust will likely accelerate the change.

The third part of the challenge is to forge consensus among states with dramatically opposed perspectives and agendas. The five-power talks resulting from the initiative of the Bush administration in 1991 is one forum in which the depth of this challenge is illuminated.

Numerous studies have addressed security problems in the Third World, and the role of arms transfers into the regions. At conferences addressing these issues, it is not uncommon to find participants from the industrialized world zeroed in on the destabilizing nature of selected weapons systems, the dangers of conflicts spilling over into other regions, and the associated dangers of wider interests of the global community being threatened by weapons proliferation. Participants from the Third World, on the other hand, emphasize the need for weapons to enhance security and deterrence, and insist on fair treatment with their foes. In these discussions, it is very difficult to reach common ground on what is equitable.[11]

The points of view highlighted above are common, and in many respects all perspectives are rational and in accord, to varying degrees, with international norms. The challenge is to reconcile the competing points of view.

Thus, the conclusion one reaches when examining past and current approaches to conventional arms proliferation is that the problem is dealt with piecemeal, on a case-by-case basis which changes with settings and circumstances. Except for the application of mandatory sanctions under United Nations auspices, nothing approaching an international regime exists to define appropriate rules, norms, and conventions governing arms transfer behavior. Whether such a regime will emerge remains unclear.

A systems approach to proliferation: understanding the problem

Having reviewed briefly the scope of the proliferation problem and the regimes for dealing with the several categories of weapons, it now is appropriate to return to the central question of this paper. Is a systems approach for proliferation appropriate, and if so, what should it involve?

By way of introducing this discussion, it is worth noting that organizational and procedural adjustments are no substitute for substance in good

11. For example, at one such recent conference sponsored by the Carnegie Endowment, scholars from India insisted on Indian security being treated on a par with China but not with Pakistan. At the same conference, participants from Israel insisted that its security requirements must be matched against the forces of a united Arab world, not against any single Arab nation. See Stahl and Kemp, *Arms Control and Weapons Proliferation in the Middle East and South Asia, op. cit.*

policymaking. Proliferation is a major substantive question, in all its dimensions. The distinct proliferation challenges posed by different types of weapons systems, the diverse kinds of expertise involved in understanding those challenges, and the range of programs across a number of agencies for addressing proliferation suggest that reorganizing the bureaucracy to better address proliferation may yield fewer positive results than some may anticipate.

This is not to suggest that some types of reorganization may not be in order. Within the intelligence community, for instance, a Nonproliferation Center has been formed with the aim to better formulate and coordinate intelligence actions in support of U.S. government non-proliferation policies.[12] Other government agencies also are adjusting their organizational arrangements for dealing with proliferation problems. However, the point to be made is that applying a systems approach to proliferations should not be understood primarily in organizational terms. It should be thought of more in terms of information management, and the role that information plays in facilitating good policymaking.

The United States government needs something akin to a single repository of institutional memory and historical data on weapons proliferation in all its dimensions, and on the policies addressing the problems posed by proliferation. This repository should be centralized, comprehensive, authoritative, and non-politicized. It should be passed on from one administration to another, serving as the corporate memory of the executive branch of government on weapons proliferation problems.

To call for a non-politicized policy archive is not to suggest that proliferation policy can be artificially segregated from national politics, nor that the policies will be the same from administration to administration. What is called for is an accurate recording -- as part of a single archive -- of the policies and the facts which led to those policies.

Any such repository would be highly sensitive for security and policy reasons. It should be maintained by the National Security Council staff, should highlight agreements and disagreements between the Executive and Congressional branches of government, and could -- to the extent feasible within reasonable guidelines of executive privilege -- be made available

12. Robert Gates, *Proliferation Testimony for Senator Glenn's Governmental Affairs Committee* (January 15, 1992), p. 14.

to both branches of government as a basis for continued discussion and debate.

Why a single repository? We have reached a point where the issues and factors involved in formulating sound non-proliferation policy have numerous cross-linkages and subtle relationships which are best exposed when viewed as part of a whole. This is not to suggest that a single policy for all areas of weapons of proliferation is in order. What it does suggest is that the process of arriving at separate policies should be informed by an improved understanding of the relationships among the various aspects of weapons proliferation. The discipline instilled by creating and maintaining a single repository would facilitate such an improved understanding.

Second, in addition to organizing and retaining the information described above, the policy process would benefit from new institutional arrangements for dealing with the information.

Net assessment is an analytic tool that has been applied successfully in a number of diverse national security areas for better understanding subregional, regional, and global military balances. The Joint Military Net Assessment (JMNA) prepared by the Chairman of the Joint Chiefs of Staff has become a valuable element in the policy dialogue within the Defense Department, and between the administration and the Congress. It establishes a common frame of reference, organizes information within that framework, and allows participants in the policy dialogues to better understand trends from year to year.

A proliferation net assessment geared specifically to the interests of the non-proliferation community, and integrated across all areas of proliferation, could begin to serve a similar function. Since the problems raised by proliferation affect so many parts of the government, this proliferation net assessment should be managed out of the National Security Council staff.

Sidney Souers, the first Executive Secretary of the National Security Council (NSC), explained in 1949 that the " most efficient conduct of ...[national security] affairs will not safeguard our national security unless all departments concerned are striving to achieve the same clearly defined and well understood objectives."[13] One can add to that the observation that effective policy formulation and implementation depends partly on common interpretations of past experiences. Policymakers and their supporting staffs should have access to systematically organized, comprehensively documented histories of non-proliferation policies and experiences, developed within a framework like that proposed in this paper.

The above suggestions address policymaking at the national level. To the extent that effective efforts at inhibiting proliferation require regional and international cooperation, a purely national data base and integrated net assessment also could serve as the basis for similar tools, in regional discussions or at the United Nations level. It also could be a mechanism for helping to organize joint U.S.-Russian cooperation of the sort called for in point six of the Camp David joint declaration, namely, "We will work actively together to prevent the proliferation of weapons of mass destruction and associated technology, and curb the spread of advanced conventional arms on the basis of principles to be agreed upon."[14]

Obviously, the question of how much information is shared among nations, bilaterally or within regional or international organizations, reflects the prevailing security circumstances of the times. However, in an area like combating proliferation, where there is widespread agreement that success requires the widest possible cooperation among different states, tools like agreed information bases, or agreed interpretations of problems and trends, can be powerful elements in forging consensus over time.

A systems approach to proliferation: safeguards

A second area in which a systems approach to proliferation is absolutely vital involves safeguards. Safeguards can be understood in several senses. IAEA safeguards, for instance, are the inspection and record-keeping activities associated with the use of nuclear materials and facilities subject to agreements between the subject countries and the IAEA. The safeguards which the Joint Chiefs of Staff called for (and received) for the nuclear testing treaties included vigorous monitoring efforts and prepara-

13. Sidney W. Souers, "Policy Formulation for National Security," *The American Political Science Review* (June 1949), reprinted in *Organizing for National Security: Selected Materials Prepared for the Committee on Government Operations, United States Senate, and its Subcommittee on National Policy Machinery* (1960), p. 37.

14. "Joint Declaration by Presidents Bush and Yeltsin," *New York Times* (February 2, 1992), p. A8.

tions against the possibility the treaties would end and the other side resumes unconstrained nuclear testing. The sorts of safeguard relevant to the current discussion are safeguards against the contingency that proliferation in fact will take place -- that efforts to stem the proliferation of weapons fails.

There are two general activities which fit into this type of safeguards. The first is a robust monitoring effort of worldwide and regional military programs, including where proliferation is taking place. The second is a security posture which can deal effectively with the effects of proliferation. To call for a systems approach with respect to those categories of activities is mainly to note that security planners cannot artificially segregate categories of weapons. Planning for threats posed by nations possessing unconventional weapons, advanced delivery systems, and conventional weapons poses a classic systems design problem: "the preparation of an assembly of methods, procedures, or techniques united by regulated interaction to form an organized whole."[15]

Planning of this sort usually takes place by examining available responses in scenarios where proliferation has taken place, e.g., in a future regional conflict where nuclear, biological, chemical, and advanced conventional weapons may be involved. The emphasis in the aftermath of the Cold War is on the options (and requisite force requirements) for the United States and its allies to respond to regional crises.[16] If a future Saddam Hussein, for instance, has unconventional weapons and advanced delivery systems, and threatens to use those weapons, how can he be effectively deterred? If he does initiate use, how can his military attack be repelled or defeated, and conflict ended on terms favorable to the United States, its interests, and allies? A systems approach illuminates the following kinds of issues:

- The U.S. has renounced biological weapons, and is prepared (in the Chemical Weapons Convention) to renounce chemical weapons. If a future Saddam Hussein threatens Tel Aviv or Riyadh, for instance, or other cities with biological or chemical weapons, how can he be de-

15. This is the DOD and NATO definition of "systems design." See *U.S. Department of Defense Dictionary of Military Terms* (Arco Publishing, 1988), p. 346.

16. "Because of the changes in the strategic environment, the threats we expect to face are regional rather than global....[O]ur plans and resources are primarily focused on deterring and fighting regional rather than global wars." Chairman, Joint Chiefs of Staff, *National Military Strategy of the United States* (January, 1992), p. 11.

terred from carrying out that threat? Are active and passive defenses sufficient? Can he be deterred through the threat of a massive conventional bombardment (along the lines of the opening air campaign of Desert Storm)? Is there a role for nuclear weapons in deterring him? If so, how can that role be reconciled with the negative security assurances associated with the Nuclear Nonproliferation Treaty?

• If a truly comprehensive nuclear test ban is achieved quickly (in the context, say, of extending the Nuclear Nonproliferation Treaty, and perhaps of concluding the Chemical Weapons Convention), yet if the current nuclear weapons states retain some level of nuclear weapons, will their nuclear weapons inventories incorporate sufficient modern safety features such as insensitive high explosives, fire-resistant pits, enhanced electronic elements, and so forth? After two or three decades of not testing, will sufficient nuclear expertise remain to inform and staff the IAEA process?[17]

• If cruise missiles, technologies to reduce radar cross sections, advanced guidance systems, and over-the-horizon targeting systems proliferate widely in the Third World, are U.S. naval forces of the type traditionally planned adequate for forward presence and crisis response missions? What about other military forces that would be projected into the crisis area?

Concluding observations

This paper has examined proliferation both as a functional issue and in

17. One of the most subtle and difficult to articulate aspects of the debate on nuclear testing involves the issue of whether Western nuclear scientists can retain sufficient knowledge of nuclear weapons processes without the experimental dimension of conducting underground nuclear tests. "The practice of technology hinges on tacit knowledge and skill -- in Polanyi's telling phrase, what people know but cannot tell (can do but not explain). Expertise comes only with experience. This is true especially in design and manufacturing, the heart of the technical enterprise. Individuals and groups make decisions -- choice of research strategies, selection of design parameters, process details -- based on what they know and can articulate, combined with tacit know-how, instinct, and intuition....Organizational knowledge -- something more than the bits and pieces of know-how embodied in a company's workforce -- reflects group learning, history and tradition, institutional style and habit...Trite as the comparison may seem, such groups resemble athletic teams in at least the following respect: no matter how capable the individuals may be, it takes time and the experience of both success and failure before the group performs at its full potential. Once broken up, engineering groups cannot be easily reconstituted, any more than gifted athletes can be quickly melded into a winning football team. Thus, for example, national security

terms of the different dimensions of the problem. There is no simple formula for dealing with proliferation. However, here -- as in the case of other complex social phenomena -- there is value in thinking about the problem from all angles, with the dimensions related to one another.

The proposals in this paper are not direct solutions to any single problem, nor are they substitutes for good staff work. One of the senior statesman of American policymaking in the trenches during the Cold War, Paul Nitze, put his finger on the reality of the matter in 1959, when he told a conference at the Mayflower Hotel in Washington, D.C., that "the making of American national policy involves immensely complex and often messy procedures."[18] That will continue to be the case. However, the policy process, for all its complexity and confusion, can be made more effective. In his 1988 Radner lecture at Columbia University, James Schlesinger argued that "there remains a profound, if disquieting, truth: in government there is no substitute for sensible men with an understanding for sensible policies."[19] A systems approach is one of the tools for arriving at such an understanding of the proliferation problem and its associated policies.

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concerns will require that the United States retain at least some experienced weapons design groups in the years ahead, no matter how much the DoD budget may decline." This passage is taken from a recent Harvard Business School and JFK School of Government Center for Science and Technology study, published as *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (1992). The passage was part of a generic example for all military technologies, but it sheds some light on the argument that with an end to nuclear testing, the national laboratories would over time (perhaps decades) lose expertise in nuclear design matters, and be in a weak position to respond to concerns some twenty or thirty years hence that a future Saddam Hussein is pursuing a nuclear weapon in unconventional ways, or to help establish the facts of the matter even if intrusive on-site inspection is allowed.

18. Paul H. Nitze, "Organization for National Policy Planning in the United States," A Paper Prepared for Delivery at the 1959 Annual Meeting of the American Political Science Association, September 10-12, 1959. Reprinted in *Organizing for National Security, op. cit.*, p. 164.

19. James Schlesinger, *America at Century's End* (Columbia University Press, 1989), p. 16.

Weapons Proliferation After the Storm: What Implications Should the United States Draw from the Iraqi Experience?

S. McKay, J. Baker
Pacific-Sierra Research

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ABSTRACT

In the aftermath of Desert Storm, numerous reassessments of the efficacy of traditional nonproliferation approaches are being undertaken. But U.S. decision makers need to distinguish between lessons unique to Iraq and those with broader implications for the U.S. policy, verification technology, and intelligence communities. This paper discusses several emerging nonproliferation issues:

- *Upgrading the effectiveness of nonproliferation regimes.* Inspections in the aftermath of Desert Storm have revealed the surprisingly multifaceted nature of the Iraqi advanced weapons programs, and have illustrated the limitations, failures, and potential benefits of current nonproliferation efforts.

- *Changing intelligence priorities in monitoring Third World weapons proliferation capabilities.* Desert Storm highlights the changing problems and issues facing the Intelligence Community, and suggests potential new challenges associated with providing direct support to international nonproliferation efforts and possible future military operations.

- *Disarmament enforcement mechanisms in a non-cooperative environment.* The current UNSCOM experience highlights new support roles and inspection modalities for implementing future U.N. sanctions or supporting peacekeeping operations. A key question is whether these emerging roles are unique to the Iraqi situation or might have future applications.

The principal authors of this paper are Steven J. McKay and John C. Baker of Pacific-Sierra Research Corporation (PSR). The authors wish to thank Brian Morra, William Koenig, Robert Martin, and Jill Jermano of PSR, and Dr. Charles Appleby of the Appleby Group for their thoughtful comments and insights. Also, the authors have benefited greatly from insights provided by officials from the UNSCOM and IAEA. Of course, the views and opinions expressed in this paper are solely those of the authors, and are not attributable to PSR or the Defense Nuclear Agency.

I. INTRODUCTION

In the aftermath of Desert Storm, the United States and other nations are reassessing the efficacy of the traditional approaches to curtail weapons proliferation. The ongoing U.N. effort to inventory and eliminate Iraq's weapons of mass destruction has yielded important insights about Saddam Hussein's ambitious programs to acquire usable nuclear, chemical, ballistic missile, and possibly biological warfare capabilities. The Iraqi inspections, directed by the U.N. Special Commission (UNSCOM) and the International Atomic Energy Agency (IAEA), highlight some new and revised nonproliferation challenges relevant to the U.S. policy, verification, and intelligence communities.

The Iraqi experience provides an indisputable "wake-up" call for the international community concerning the need to address the weapons proliferation problem. But U.S. policymakers and technical experts should make careful distinctions between lessons unique to Iraq and those with broader implications for dealing with the continuing challenge of weapons proliferation.

The following highlights the key implications from each of these areas drawn from the more detailed discussion provided in Sections III to V.

IMPLICATIONS FOR CURRENT TECHNOLOGY CONTROL REGIMES

- The worldwide proliferation of special weapons technology and the increasing role of Third World suppliers, combined with the demonstrated utility of older technology and systems, pose significant challenges to any export control regime limited to the highly industrialized world.
- However, it can be argued that in addition to these inherent limitations, poor coordination and implementation among the Western supplier states, from basic policy goals to technical issues regarding dual-use items, also contributed to the development of Iraq's weapons programs.
- And finally, even imperfect control regimes can increase the cost and complexity of these special weapons programs and help dissuade marginal proliferants, while at the same time, provide a political framework for action, and yield important intelligence benefits against more determined states.

INTELLIGENCE IMPLICATIONS

- The problem of coping with rapid change in the former Soviet Union, coupled with the difficulty of developing solid intelligence on emerging priority issues, such as weapons proliferation, suggest that the IC will have difficulty generating a commensurate level of understanding for individual Third World target states, such as Iraq, as was generated for the Soviet Union.

- In addition, as Third World weapons programs mature, the intelligence requirements will correspondingly need to shift away from purely proliferation-oriented issues and towards greater operational intelligence that may be required to support potential future military actions.

- And lastly, the success of UNSCOM and IAEA inspections in Iraq illustrate the value of the unprecedented level of intelligence support that the United States and other governments have provided; however, it is currently unclear whether this experience will be unique to Iraq or can be repeated in the future.

DISARMAMENT ENFORCEMENT IMPLICATIONS

- The U.N.-sponsored inspections succeeded in detecting prohibited activities, despite vigorous Iraqi countermeasures, because of such factors as the right to conduct very intrusive inspections, timely intelligence from national governments, unanimous support from the U.N. Security Council, and the threatened use of Coalition military force to overcome Iraqi intransigence.

- The inspections also highlight the advantages of being self-sufficient in transportation assets and logistical support, and identified the need for some improved verification technologies, such as a capability for on-site sample analysis to support nuclear inspections.

- And lastly, the effectiveness of inspection teams was markedly improved by combining international inspectors with national experts who have special knowledge of the equipment and facilities used in developing both modern and first-generation weapons of mass destruction.

The paper which follows is organized along the basic structure of the proliferation problem itself. Namely, in the front-end we discuss efforts to curtail weapons proliferation, both in terms of how Iraq was able to foil current regimes to build its weapons programs (Section II) and what implications Iraq's efforts entail for these regimes (Section III). Section IV follows with the discussion of foundation of technology control and enforcement efforts – intelligence. Following this, Section V discusses the back-end of the proliferation problem – the enforcement regimes. And, finally, Section VI concludes with a summary of the key observations from this analysis.

recent experience of the North Korean vessel suspected of shipping Scud missiles and production equipment to Iran and Syria was used to illustrate the need for expanding the MTCR beyond the current list of signatories.

And, lastly, these regimes have important intelligence benefits because they provide an important structure to the problem of monitoring a country's activities. For example, former CIA Director William Webster stated that

> "if a country refuses to join a nuclear control regime, we have a clear signal that we should focus additional attention on its nuclear development programs, and we certainly do. From my perspective, the Non-Proliferation Treaty and the activities of the International Atomic Energy Agency help us use our intelligence resources more effectively to track nuclear developments."[42]

Thus, *by providing potential indications of intent and warning, export control regimes and their inspection and data notification activities, can serve a valuable intelligence function.*

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[42] See *Nuclear and Missile Proliferation*, p. 11.

II. IRAQ'S WEAPONS PROGRAMS

Saddam Hussein's determination to add weapons of mass destruction to Iraq's arsenal is reflected in both the physical and documentary evidence acquired by the U.N. inspections. Prior to the Gulf War, Iraq had ambitious acquisition programs in the chemical, nuclear, and ballistic missile fields. The Iraqis seem to have adopted a parallel approach aimed at fielding usable military capabilities in the near-term while developing more sophisticated systems for the longer run. Hence, they drew heavily on foreign suppliers while building up Iraq's indigenous infrastructure for weapons development and production. By examining the information that has come forth from these inspections and from authoritative government, academic, and private analyses, it is possible to piece together the key elements of Iraq's special weapons programs.[1]

NUCLEAR WEAPONS

To the surprise of most outside experts, the postwar IAEA inspections of Iraq revealed a more sophisticated and multi-faceted nuclear weapons development program than previously estimated. Embedded within Iraq's nuclear program was a large-scale clandestine effort that skillfully brought together the expertise, equipment and facilities necessary for developing and producing nuclear weapons. The program was largely centered at the Al Tuwaitha Nuclear Research Center near Baghdad, with specialized production and testing facilities located throughout the country. Although a debate still exists on when Iraq could have acquired a nuclear device had Desert Storm not occurred, there is little disagreement that the U.N. inspections have revealed convincing evidence of Iraq's determination to acquire a nuclear weapons capability.[2]

Iraq explored several routes for acquiring nuclear weapons-grade material. Rather than selecting one approach, the Iraqis invested substantial resources in two parallel routes for acquiring highly enriched uranium: a centrifuge

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[1] For the purposes of this paper, 'special weapons' refers to nuclear, chemical, and biological weapons, as well as ballistic missiles and Iraq's Supergun program.

[2] The IAEA inspectors early on estimated that the Iraqis were "12 to 18 months away from the acquisition" of sufficient nuclear weapons-grade material at the time of the Gulf War. More recent assessments have suggested that Iraq probably would have required at least twice as long to produce sufficient enriched uranium for a nuclear weapon. By these estimates, Iraq probably could not have acquired a "small nuclear arsenal" until the mid-1990s. See *Nuclear Proliferation: Learning from the Iraq Experience*, Hearing before the Committee on Foreign Relations, United States Senate, 17 & 23 October 1991, p. 20; D. Albright and M. Hibbs, "Iraq's Bomb: Blueprints and Artifacts," *The Bulletin of the Atomic Scientists*, January/February 1992, pp. 31-32, 40; and P. Lewis, "U.N. experts now say Baghdad was far from making an A-bomb before Gulf War," *New York Times*, 20 May 1992.

enrichment program and an approach using the electromagnetic isotope separation (EMIS) technique.[3] The Iraqi centrifuge program benefited substantially from the acquisition of critical knowledge and materials from foreign sources. In comparison, the EMIS program was largely developed using indigenous resources. The unexpected discovery by U.N. inspectors of Iraq's calutron facilities for the EMIS process led U.S. nuclear weapons experts to express their surprise over these "living dinosaurs" because the United States had abandoned this enrichment technology in the late 1940s as more efficient methods became available.[4] The Iraqi effort also had an active weaponization program that included work on the necessary computations and high explosive testing associated with developing an implosion type nuclear device.

CHEMICAL AND BIOLOGICAL WEAPONS

At the time of Desert Storm, the Iraqis possessed substantial stockpiles of chemical weapons (CW) both in the form of bulk agent stores and an estimated 50,000 pieces of field munitions including artillery and rocket shells, bombs, and Scud warheads.[5] Most of these munitions are located at Iraq's large CW production, filling, and storage site at Al Muthanna. As a result of air attacks during Desert Storm, and the Iraqi's relatively slipshod CW handling practices, Al Muthanna and other CW facilities are hazardous sites to inspect because of the presence of unexploded ordnance and leaking chemical munitions.[6]

In contrast to its extensive CW capability, Iraq formally denied possessing biological weapons (BW) in its cease-fire declarations concerning weapons of mass destruction. But once the U.N. inspections began, the Iraqis admitted to having an active BW research program between mid-1986 and August 1990. To date, no evidence of Iraqi biological weapons or a weaponization program has been uncovered by the postwar U.N. inspections. Nonetheless, Iraq's reluctance

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[3] The Iraqis also admitted to conducting limited work on another method for uranium enrichment known as chemical exchange. See U.N. Security Council document no. S/23165 (25 October 1991), pp. 21-23; and *Nuclear Proliferation: Learning from the Iraq Experience*, pp. 15, 18.

[4] G. Zorpette, "Part 1: How Iraq Reverse-engineered the Bomb," *IEEE Spectrum*, April 1992, pp. 24, 63-64; and S. Hedges and P. Cary, "Saddam's Secret Bomb," *U.S. News and World Report*, 25 November 1991, pp. 34-38.

[5] Interview, "Ambassador Rolf Ekeus: Unearthing Iraq's Arsenal," *Arms Control Today*, April 1992, p. 8.

[6] Ibid., pp. 7-8; and U.N. Security Council document no. S/23165, pp. 26-29.

to provide real documentation on its past BW activities fuels the concern of U.N. inspectors over the function of certain laboratory facilities.[7]

BALLISTIC MISSILES

In the area of ballistic missiles, Iraq again engaged in a multi-faceted program whose primary goal was to develop an assured delivery means against key regional targets. The genesis of Iraq's missile arsenal occurred in the early 1970s when, according to one source, Iraq first received Scud-B short-range ballistic missiles from the Soviet Union.[8] By the beginning of the Iran-Iraq war, Iraq still allegedly possessed only a limited quantity of Scuds, and these did not represent a militarily effective force.[9] In the decade that ensued, however, Iraq progressively increased its ballistic missile capabilities. The Scud-B played an increasingly larger role in the Iran-Iraq war, but had only enough range (i.e., 300 km) to strike targets in the rear of the immediate battlefield.[10]

Recognizing this key limitation, Saddam pursued several parallel programs to acquire a missile capability with sufficient range to strike Tehran and, perhaps more importantly, Israel.[11] Iraq's participation in the Condor 2 missile development program with Argentina and Egypt has been well documented.[12] Initially limited to financial sponsorship, the Condor program also reportedly served as a means for Iraq to develop its own solid propellant ballistic missile

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[7] U.N. Security Council document no. S/23165, p. 30; Zorpette, pp. 7-8; and interviews with UNSCOM inspectors.

[8] W.S. Carus and J. Bermudez, Jr., "Iraq's Al-Husayn Missile Programme," *Jane's Soviet Intelligence Review*, May 1990, p. 204.

[9] A. Cordesman and A. Wagner, *The Lessons of Modern War, Volume II: The Iran-Iraq War*, (San Francisco: Westview Press, 1990), pp. 497.

[10] See Cordesman, p. 497 for estimates of Iraqi Scud launches during the Iran-Iraq War.

[11] A number of good sources exist detailing Iraq's missile programs. See, for example, Carus and Bermudez (May 1990); W.S. Carus, *Ballistic Missiles in the Third World: Threat and Response*, (Washington, D.C.: The Center for Strategic and International Studies, 1990); Cordesman, pp. 495-506; D. Lennox, "Iraq's 'Scud' programme – the tip of the iceberg," *Jane's Defence Weekly*, 2 March 1991, pp. 301-303; Brig. Gen. A. Levran, "Threats Facing Israel From Surface-to-Surface Missiles," *IDF Journal*, Winter 1990, p. 39; J. Nolan, *Trappings of Power – Ballistic Missiles in the Third World*, (Washington, DC: Brookings Institution, 1991); Col. J. O'Pray, *Regional Power Ballistic Missiles – An Emerging Threat to Deployed US Forces?*, (U.S. Air Force, Air War College, 1990); and K. Timmerman, *The Death Lobby – How the West Armed Iraq*, (New York: Houghton Mifflin Company, 1991).

[12] See references above, particularly, Nolan, pp. 53-54; and Timmerman, pp. 142-160.

program.[13] Although the Condor effort came under intense scrutiny by the United States, eventually forcing Argentina to withdraw, Iraq's advanced missile efforts apparently continued. Media reports and congressional testimony on the progress of inspections following the war have shown that despite the combined effects of these earlier diplomatic efforts and military actions taken during Desert Storm, Iraq still retained some of its Condor production base.[14]

Iraq's other major ballistic missile program involved a series of modifications to the basic Scud-B. Reportedly with help from foreign sources, Iraq developed a series of missiles derived from the Scud by reducing the size of the warhead (the *Al-Husayn*), lengthening the airframe (the *Al-Abbas*), and clustering airframes for a long-range variant (the *Al Aabed* and *Tammouz*).[15] While the technology in these systems is mostly 1950s vintage, the contribution of the *Al-Husayn* in ending the Iran-Iraq War and, most importantly, the recent experiences in Desert Storm, illustrate the political and military impact that even relatively unsophisticated systems can have.

A key uncertainty over Iraq's Scud and Scud-variant inventory is based on poor knowledge of its original inventory supplied by the Soviets and how many, if any, Iraq was able to produce on its own or acquire from other sources. The threat that Iraq may still possess elements of these missile programs has caused great concern within the Bush Administration and the U.N., and is a major focus of the continuing inspection mission in Iraq.[16]

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[13] Reportedly known as "Project 395," Iraq's solid propellant missile program presumably drew heavily from developments in the Condor effort, but was intended to be for exclusive Iraqi use. See Carus and Bermudez (May 1990), pp. 204-205; "Missile sites approach completion in Iraq," *Flight International*, 13 May 1989; Nolan, p. 56; and Timmerman, pp. 255-256.

[14] Numerous high-level Administration officials have testified to this fact. For example, in testimony before the Senate Committee on Governmental Affairs on 15 January 1992, CIA Director Robert Gates stated that "we believe a number, perhaps hundreds, of Scud missiles and much Scud and Condor production equipment remain." A U.N. photograph published in the *Washington Post* illustrating a casting pit for large-diameter solid propellant rocket motors provides further indication that some Condor production remained following the war; see T. Rowe and R. Smith, "Iraq makes new concession to U.N.; U.S. officials view move skeptically," *Washington Post*, 21 March 1992, pp. A1, A19.

[15] See references above, particularly, Carus and Bermudez (May 1990), pp. 205-206; Cordesman, pp. 499-500; Lennox, p. 301; Nolan, p. 55; and Timmerman, pp. 248-255, 289-90. For other reports on Iraq's long-range missile developments, see "Iraq claims to test missile able to launch satellite," *Defense Daily*, 11 December 1989; "Iraq reports second long-range missile test," *Defense Daily*, 15 December 1989; and "Iraq launches home-made ICBM," *Defense Electronics*, February 1990, p. 16.

[16] According to one report, the U.N. estimates that the Soviets delivered about 800 Scud-Bs to Iraq. An authoritative Soviet source estimates that Iraq had over 500 missiles (presumably a mix of Scud and Scud-variant), 30 fixed launchers, and around 36 mobile launchers at the beginning of Desert

SUPERGUN

Lastly, as an extension to the ballistic missile program and Saddam's efforts to deliver long-range strikes against Israel, the Supergun program further illustrates Iraq's diversified and ambitious weapons programs. As CIA Director Gates stated in January of this year, the Supergun illustrates what may be a growing trend toward more sophisticated weapons programs in Third World countries.[17] Like the Condor and Scud modification programs, the Supergun was yet another example of Iraq pursuing a parallel program to develop an assured delivery means against targets in Israel.[18] However, through a combination of export controls applied by the United States and United Kingdom and the alleged assassination of designer Gerald Bull in March 1990, Iraq was unable to complete the program by the time of Desert Storm.[19]

SUMMARY

The ambitious nature of Saddam Hussein's program probably reflects the distinctive factors at work in Iraq's case. These include the following:

- The wartime urgency provided by the continuing Iran-Iraq war,
- Iraq's bolstered commitment to acquiring weapons of mass destruction, including an effort toward distributed parallel efforts to reduce the programs vulnerability, following Israel's air strikes on the *Osiraq* nuclear reactor in 1981,
- A firm commitment to these weapons programs by a dictatorial leader with great power aspirations,
- The apparent absence of any major funding constraints, at least not until the later stages of the Iran-Iraq War,

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Storm. Administration statements have cited the possibility that Iraq may still retain "hundreds of Scuds" in defiance of U.N. Resolution 687. See, G. Leopold, "U.N. documents Iraq's arms efforts," *Defense News*, 4 November 1991, pp. 4, 29; Col. V.P. Chigak, "The first lessons of the war," *Voennaia mysl'*, No. 5, May 1991, p. 64; and testimony of CIA Director Gates (15 January 1992), p. 7.

17 Testimony of CIA Director Gates (15 January 1992), p. 2.

18 A number of good sources are available describing the Iraqi Supergun program. See, for example, W. Lowther, *Arms and the Man: Dr. Gerald Bull, Iraq and the Supergun*, (Novato, CA: Presidio Press, 1991); and W. Malone, et al, "The Guns of Saddam," *Washington Post*, 10 February 1991, pp. C1, C4.

19 For a discussion of Western export control efforts against the Supergun, see references above, plus B. Gertz, "West thwarted Iraqi supergun," *Washington Times*, 1 April 1991, p. A3; and G. Frankel, "U.S., Britain Knew of Supergun, Designer Says," *Washington Post*, 16 January 1992, p. All.

- A well developed industrial infrastructure and manufacturing capability,

- And finally, a relatively sophisticated network for acquiring needed information and material from abroad while concealing the full extent of weapons development efforts at home.

In combination, these factors made Iraq both a very determined and resourceful proliferant.

In the aftermath of the Gulf War, the remaining elements of Iraq's weapons programs, particularly the scientists, engineers, and skilled technicians who staff them, will continue to pose a monitoring challenge. As stated by CIA Director Gates, in the absence of effective and continuing U.N. monitoring, this "cadre of scientists and engineers trained for these programs will be able to reconstitute any dormant program rapidly."[20] Prior to discussing the implications of this challenge, the avenues by which Iraq acquired these capabilities are examined and the implications that these pose for current nonproliferation regimes are assessed.

[20] Testimony of CIA Director Gates (15 January 1992), p. 8.

III. IMPLICATIONS FOR CURRENT TECHNOLOGY CONTROL REGIMES

By most accounts, Iraq was able to develop its special weapons programs despite the existence of a variety of national and international export control regimes designed to prevent just this outcome. A key reason for this development is the increasing availability of usable technology, both from the West and, increasingly, from Third World suppliers. However, Iraq also points toward some dramatic failures in coordination and implementation among the chief supplier states. Despite these limitations and failure, though, the Iraq experience does suggest some benefits from the current system of export controls. To illustrate these points, this section will first briefly examine the reported avenues that Iraq took to establish its weapons programs.

IRAQ'S ACQUISITION PATHS

Iraq's nuclear, chemical, and ballistic missile programs show a common pattern of parallel development efforts, each taking a different technological approach to achieve a common goal. For example, while Iraq was involved in the Condor project with Egypt and Argentina to develop a short-range solid propellant ballistic missile, it also engaged in the Scud modification program, an indigenous solid propellant missile program, and the Supergun effort. It can be argued that the ultimate goals of this comprehensive program were twofold: (1) early achievement of an assured strike capability against Israel and Tehran, and (2) a more ambitious program to build an indigenous missile capability to be used as a tool for regional and Arab leadership.

The nuclear program also shows that Iraq employed at least three parallel techniques for producing enriched uranium (i.e., centrifuges, calutrons, and chemical exchange). Similarly, in the chemical weapons arena, Iraq also was reportedly involved in numerous efforts. Several factors probably account for Iraq's multi-faceted approach to weapons development:

- Need for early availability,
- Goal of reduced vulnerability,
- Hedge against technological uncertainty, and
- Absence of severe funding constraints, at least not until the later stages of the Iran-Iraq War.

Iraq's approach can be seen as a logical reaction to Israel's successful raid on the *Osiraq* nuclear reactor in 1981. Rather than emphasizing any single program or facility, Saddam may have wished to distribute his development efforts to lessen the risk of an outside power, such as Israel or Iran, being able to repeat the success of the raid on the nuclear facility.[21] Alternatively, these parallel efforts can be seen as the product of a basic technological uncertainty over which method would produce the desired results more quickly.[22] Given the overriding goal of the early possession of weapons of mass destruction and the means of delivering them, Saddam may have simply not been interested in precisely how it came about, and was willing to invest in the costly infrastructure, material, and personnel required to develop these alternative paths.

As an extension of these programs, Iraq's acquisition programs also followed numerous parallel paths, presumably both to reduce the risks of potential disruptions in supply from export controls and as a product of the basic technological uncertainty regarding particular techniques. For example, the IAEA has reported that Iraq established "a large, secure and highly successful procurement network." By this account, Iraq had a three-tiered procurement strategy including: (1) "the use of other Iraqi State establishments as buyers and contractors," (2) "the placing of orders for equipment ... directly with foreign manufacturers and indirectly through foreign intermediaries," and (3) "the utilization of indigenous capabilities to complete the manufacture of some items."[23] Using this complex web of front-companies and Western intermediaries, Iraq was able to skirt a variety of export control laws.

There have been numerous media reports alleging the involvement of Western firms and the major industrialized countries in the development of these programs.[24] Some of these have been confirmed as a result of the

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21 This point is argued by Timmerman (pp. 103-105) in his account of Saddam's reaction to the Osiraq bombing and the subsequent decision to more widely distribute Iraq's special weapons development efforts. In particular, Timmerman notes that Iraq chose to pursue the enriched uranium route, which could be produced at relatively small facilities, rather than continuing to emphasize plutonium production at relatively large, visible reactors.

22 This explanation has been used when comparing Iraq's nuclear efforts with the United States' original Manhattan Project. For a good discussion on this topic, see D. Albright and M. Hibbs, "Iraq's Shop-Till-You Drop Nuclear Program," *The Bulletin of the Atomic Scientists*, April 1992, pp. 27-37.

23 IAEA, *Report on the Eighth IAEA On-Site Inspection in Iraq Under Security Council Resolution 687*, excerpted in *Nuclear Proliferation: Learning from the Iraq Experience*, pp. 54-55. See also, A. Friedman, et al, "Britain says Iraqi 'undercover network' taps West's technology," *Financial Times*, 13 September 1990, pp. 1, 26. In addition, Timmerman presents a comprehensive reporting on Iraq's acquisition efforts.

24 See for example, "Solid fuel components licensed for export to Iraq by Commerce Department," *Inside the Pentagon*, 1 July 1988, p. 14; "3rd world missile linked to German, Italian firms," *Los Angeles Times*, 8 February 1989, p. A5; "U.S. Firms Helped Iraq Gain Ability to Make Missiles, Officials Say," *Washington Post*, 3 May 1989, p. A19; "U.S. Approves Export of Rocket Parts to

information obtained by U.N. inspectors.[25] Others remain to be tracked down as UNSCOM and IAEA officials sift through the voluminous documentation that has been recovered from Iraq. Foreign involvement has reportedly ranged from the transfer of complete weapons systems and turn-key plants, to the manufacture and sale of small subcomponents. In several instances, Iraq reportedly acquired the design for a system or facility from one firm or country, and then used it as a shopping list to acquire individual components and equipment from numerous other suppliers.[26] In addition to the security benefits of being able to contract subcomponents to multiple firms, essentially compartmentalizing the acquisition program, the Iraqi engineers and program managers probably also benefited from the resulting interchanges with their Western counterparts as a result of the negotiation and bidding process.

LIMITATIONS OF EXPORT CONTROLS

Consideration of the Iraqi special weapons programs highlights three points that have broad implications for the current system of controls on nuclear, chemical, biological, and ballistic missile technologies. First, and foremost, the Iraq experience has dramatically highlighted the inherent limitations of Western technology controls and has served as a 'wakeup call' to the fact that dual-use technologies and expertise have already proliferated widely throughout the

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Brazil Despite Fears of Link to Iraq," *New York Times*, 7 September 1990, p. A8; "Iraq may gain from U.S. exports to Brazil," *Financial Times*, 8 September 1990, p. 2; "U.S. Officials Ignored Objections to 'Dual-Use' Exports to Iraq," *Financial Times*, 19 September 1990, p. 2; "American Sales to Iraq Totaled $1.5 Billion," *Washington Post*, 1 November 1990, p. C1; "Germans reportedly helped Iraq with Scuds," *Washington Post*, 25 January 1991, p. A29; "Despite warning, U.S. OK'd sale of missile parts to Iraq," *Los Angeles Times*, 9 April 1991, p. A7; L. Weymouth, "Third-World nukes: The German connection," *Washington Post*, 13 December 1991, p. A29; and M. Wise, "Iraq provides names of 3 firms that aided its A-arms program," *Washington Post*, 19 May 1992, p. A15.

25 See, for example, "U.N. documents Iraq's arms efforts," p. 29; F. Gaffney, "'Gotcha': U.N. teams finds Germans engaged in missile proliferation," *Decision Brief from the Center for Security Policy*, 2 January 1992.

26 Timmerman (pp. 36-38, 48-49) cites an example of this pattern in his discussion of Iraq's approach to a U.S. chemical firm, purportedly under the guise of developing a pesticides research facility. After extensive negotiations, the U.S. firm backed out of the deal out of concern that the plant would be used for manufacturing chemical weapons. According to this account, however, Iraq was able to use the plans acquired from the firm to approach other Western firms for actually building the facility. A similar example reportedly exists in the nuclear program where the Iraqis undertook protracted technical negotiations with French developers of the chemical exchange method for uranium enrichment. Once the Iraqis had acquired substantial knowledge about this process, they terminated the negotiations and began buying relevant patent information and equipment to develop the process on their own. See, Zorpette, p. 23.

Third World.[27] *With reports of Argentina, Brazil, and Egypt playing major roles in Iraq's Scud modification and Condor projects, it is clear that Third World suppliers and advisors will play increasingly major roles in the special weapons programs of other Third World states.*[28] The diffusion of advanced technologies can also be seen in the number of other Third World countries that are developing indigenous advanced weapons and space programs.[29] Moreover, given the export incentives for countries to develop indigenous production capabilities, this trend is not likely to decline in the near future.[30]

The level of technology that can be obtained from Third World suppliers ranges from the relatively advanced, sometimes derived from Western sources, to relatively rudimentary systems. However, *Iraq's successful employment of the 1950's vintage Scud and the use of 1940's vintage calutrons illustrates that high-tech solutions are not the sole determinant of a successful weapons program, and that simple but effective low-technology solutions are often available.* For example, the Director General of the IAEA, Dr. Hans Blix recently commented to the effect that one of the benefits for the Iraqis of using the calutron technology was the ability to undertake the program without outside

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27 This view was supported by former CIA Director William Webster when he stated that "...much of the technology critical to ballistic missile development was passed from the developed to the developing world long ago. Now we find Third World countries sharing technology, pooling their resources and technical know-how in areas such as solid rocket fuel production. Countries that a few years ago were wholly dependent on foreign suppliers for their own missile programs are now re-transferring technology to new Third World missile development efforts." See *Nuclear and Missile Proliferation*, Hearing before the Committee on Governmental Affairs, United States Senate, 18 May 1989, p. 13.

28 See, for example, "Egyptians Update Iraqi Missiles," *Chicago Tribune*, 5 May 1988, p. A28; J. Dorsey, "Brazil Arms Trade Has U.S. Worried," *Chicago Tribune*, 5 March 1989, p. 23; "Iraq gets Chinese aid on A-bomb," *Washington Times*, 14 December 1989; "Brazilian Arms Experts said to Upgrade Iraq's Missiles," *Wall Street Journal*, 30 August 1990, p. A5; "U.S. Approves Export of Rocket Parts to Brazil Despite Fears of Link to Iraq," *New York Times*, 7 September 1990, p. A8; Timmerman, various sections; R. Bitzinger, *Chinese Arms Production and Sales to the Third World*, (Santa Monica, CA: The Rand Corporation, 1991); and "Firm 'May Have' Sold Missile Technology to Iraq," Rio de Janeiro Rede Globo Television (in Portuguese), 2155 GMT 3 January 1992, translated in JPRS-TND-92-004, p. 8.

29 The efforts toward developing ballistic missiles and space launch vehicles in India and Brazil, offer two examples, as do the alleged nuclear weapons programs of Pakistan, Israel, and India.

30 The export incentive is often cited as Brazil's principal motivation in developing a variety of weapons programs, and has led this country to become one of the Third World's largest weapons exporter. China is also seen as having a strong export motivation for its weapons systems as a means of supporting the development and production of more advanced weapons for the People's Liberation Army. Bitzinger argues this last point on p. 5 of his study.

help.[31] Because the technical design information for this program was largely acquired from open literature sources in the West, the calutron program also illustrates the special problem of older technology approaches available from Western academic and technical journals and exchanges.

Furthermore, developing crude but militarily useful weapons of mass destruction does not require Third World proliferants to achieve the same level of sophistication in technologies and methods as found in U.S. weapons programs. It is worth remembering that the initial approaches for developing atomic weapons are nearly 50 years old and predate the availability of advanced measuring systems and computing capabilities. In many cases, Third World proliferants can pursue design solutions to surmount weapons development problems that Western experts might consider technically crude, economically inefficient, or insufficiently reliable.

Thus, in summary, high technology solutions continue to be proliferated and can be obtained both from Western and, increasingly, other Third World suppliers. In conjunction with the fact that even low-technology approaches can offer cost-effective design and weapons solutions, the task of nonproliferation regimes is becoming increasingly more difficult. If more effective weapons proliferation regimes are to be enacted, greater efforts will be required to broaden the list of current and potential future suppliers committed to adhering to these agreements, and in reexamining the control and availability of older but still useful weapons technology.

COORDINATION AND IMPLEMENTATION DIFFICULTIES

In addition to increasing spread of technology within the Third World, the fact that a number of Western firms and governments did allegedly supply Iraq's weapons programs with knowledge and material, either knowingly or unknowingly, points toward a basic underlying weakness in the current nonproliferation strategy. Essentially, *voluntary export control regimes can only be as strong as the willingness of its members to adhere to it in a uniform and coordinated fashion.* Iraq illustrates the potential impact when other policy imperatives conflict or even over-ride the mandate of such export control regimes. Thus, the political goals of supporting Iraq in its war against Iran and of reducing Soviet influence in this key Gulf state, may all have been deemed more important than halting the proliferation of special weapons technology to this country.

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[31] Dr. Blix' exact statement was that "the calutron program seems to have been sustained mainly by indigenous means, and very little, if any, international components entered into [the] program." See *Nuclear Proliferation: Learning from the Iraq Experience*, p. 34.

Another problem occurs when supplier states disagree on the general approach to a nonproliferation problem. Even given a shared objective to halt proliferation, nations may still differ on the best approach and methods to achieving this objective. One source quotes a French official acknowledging this point while complaining about U.S. protests regarding a French firm's alleged involvement in the Iraqi missile program. According to this official, the French government

> "... had different notions of how best to enforce the MTCR. Our view was that we could be more effective in keeping an eye on worrisome missile programs as they were developing if we showed some cooperation and understanding to the countries involved."[32]

Reportedly, the United States strongly objected to this stance and pushed the French government to act on evidence of the firm's role in Iraq.[33] Such differences in policy and approach can seriously erode the political foundation for cooperation in controlling weapons proliferation.

Finally, a last area that has been difficult to coordinate and may have contributed to Iraq's weapons development involves coordination at the legal and implementation level. Ultimately, implementation of export control regimes falls to the legal system of each participating country to enact proper legislation to either bar or mandate licensing and approval for the export of designated items, and to provide penalties for firms or individuals in violation of this legislation. Unlike in the United States, several of the Western supplier states lack effective 'end-user' provisions in their export laws. Thus, for example, a French firm could reportedly transfer equipment and technology to Iraq without violating export provisions regarding sales to countries at war by simply selling to a Western front company. Thus, without effective export laws and 'end-user' monitoring, and often facing weak penalties, many Western firms reportedly engaged in illegal sales to Iraq.

Lastly, an area that has compounded each of the above mentioned problems concerns the difficulty of drawing the line among 'dual-use' equipment that should be controlled, and the difficulty of controlling the proliferation of human

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32 See Timmerman, pp. 267-269.

33 Timmerman also paraphrases a comment by former Assistant Secretary of State Richard Perle that U.S. "...demarches just bounced off the allies like marshmallows." Mr. Perle's sentiment is also referenced in the prepared statement of Senator Jeff Bingaman, and in later testimony during this hearing where Mr. Perle's use of the term "demarche-mallows" was referenced. Also, Senator John Glenn echoed these sentiments in this hearing when he stated that "we see report after report of weaknesses in the nuclear export control systems of our closest friends and allies and have witnessed for years the resistance of these friends and allies to our long-standing concerns about these problems." See *Nuclear and Missile Proliferation*, pp. 2, 6, 44.

knowledge. The problem of 'dual-use' equipment and technology has been a difficult problem to resolve, both within the U.S. government and among the supplier states. For example, an ACDA official has stated that

> "the Missile Technology Control Regime, like all supplier restraint agreements, works imperfectly. Sometimes there are differences of view among the partners as to exactly what can be exported and under what conditions; for example, whether support for certain space launch vehicle programs is consistent with the regime's guidelines."[34]

Often the technologies involved have many civilian applications, and the question of what to control becomes an issue of differentiating among numerous shades of gray. Frequently, decisions in this area become points of political and bureaucratic contention. There have been numerous media and congressional reports of differences within the past few Administrations over specific export licenses and more general issues of what items fall within current export regimes.[35] Along with media coverage of some disputed U.S. technology sales to Third World countries, these internal problems could easily have been used in Allied arguments in defense of their own export practices.[36]

Thus, it can be argued that the difficulties in controlling special weapons technologies are not simply a function of the control regimes, nor of the state of technology availability. Rather, *the Iraq experience shows that poor coordination among supplier states, at all levels of basic policy and approach, and down toward legal mechanisms and technical discussions of what constitutes a controllable item, constituted a major stumbling block to effective nonproliferation efforts.* Fortunately, many of these difficulties have been addressed and during the last few years a much greater consensus has been achieved among the major supplier states. Unfortunately, however, it was

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[34] Statement of Norman A. Wulf, former Deputy Assistant Director, Bureau of Nuclear Weapons Control, U.S. Arms Control and Disarmament Agency, found in *Missile Proliferation: The Need for Controls (Missile Technology Control Regime),* Hearings before the Subcommittees on Arms Control, International Security and Science, and on International Economic Policy and Trade of the Committee on Foreign Affairs, United States House of Representatives, 12 July and 30 October 1989, p. 41.

[35] See the statement by Senator Bingaman and testimony by Ambassador Ronald Lehman, Director of the Arms Control and Disarmament Agency, on the lack of coordination among the Departments of Commerce, State, and Defense on these matters in *Nuclear and Missile Proliferation*, pp. 7 & 47. See also, Timmerman, pp. 239-41, 266-67.

[36] See, for example, "U.S. Approves Export of Rocket Parts to Brazil Despite Fears of Link to Iraq," *New York Times*, 7 September 1990, p. A8; "Iraq may gain from U.S. exports to Brazil," *Financial Times*, 8 September 1990, p. 2; "U.S. Officials Ignored Objections to 'Dual-Use' Exports to Iraq," *Financial Times*, 19 September 1990, p. 2; and "Despite warning, U.S. OK'd sale of missile parts to Iraq," *Los Angeles Times*, 9 April 1991, p. A7.

during the period of contention during the 1980's and before that Iraq made the greatest strides in these weapons areas, so that by the late 1980's when this consensus began to coalesce, the cat was out of the bag, so to speak. By this time Iraq had acquired a substantial domestic capability to develop and produce these systems.

IAEA Experience in Iraq

For this reason, critique of the IAEA over supposedly failing to prevent Iraq's progress towards nuclear weapons capability is partly misplaced. Certainly, the IAEA safeguards regime can be improved, and there have been several good analyses in this area.[37] However, it must be recognized that the IAEA is not designed as a comprehensive monitoring and verification body. Rather, as Senator Glenn, one of the original congressional backers of the IAEA, has stated, the safeguards regime is "...an information gathering system that lets the rest of the world know through IAEA what is going on with proliferation around the world." On the limits to what the IAEA can do in this area, the Senator also stated that

> "while its member states insist in holding the [IAEA] to a 'zero growth budget,' the world community is giving the agency more and more and more work to do. Walter Lippmann once said a foreign policy risked becoming 'insolvent' when a nation's ambition exceed its available resources. The IAEA faces a similar risk today."[38]

Thus, within the constraints imposed by its charter, the IAEA tried to perform its mission to monitor Iraqi nuclear developments. Certainly, mistakes in judgment may have been made. However, the more important lessons for nuclear nonproliferation are likely to be found in the nature of the IAEA charter and in the degree to which the IAEA member states adhered to its intent, rather than in the conduct or conclusions of particular safeguards inspections. Moreover, examination of the MTCR signatories' reported export practices, both before and after the 1987 signing of this agreement, yields mostly similar conclusions regarding the utility of this export control regime.

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37 See, for example, P. Leventhal, "Plugging the Leaks in Nuclear Export Controls: Why Bother?," *Orbis*, Spring 1992; L. Dunn, *Containing Nuclear Proliferation*, Adelphi Papers 263, International Institute for Strategic Studies, Winter 1991; M. Krepon, "Iraq Inspections Offer Lessons to U.S.," *Defense News*, October 7, 1991, p. 23; and L. Scheinman, *The International Atomic Energy Agency and World Nuclear Order*, (Washington, D.C.: Resources for the Future, 1987).

38 *Nuclear Proliferation: Learning from the Iraq Experience*, pp. 5-6, 8.

BENEFITS OF EXPORT CONTROL REGIMES

For the reasons cited above, Desert Storm and its aftermath certainly highlight the limitations of current export control regimes. However, it is also important to point out the benefits of these export controls. First, they have made it more difficult for countries like Iraq to acquire special weapons technologies. By forcing countries to use covert acquisition methods, they increase the complexity of these programs. Also, in the face of potential legal and diplomatic sanction, these regimes can push suppliers to charge increasingly higher costs for their technology. *The net effect of the export control regimes, therefore, is likely to be increased costs and longer development and acquisition times for these special weapons programs.*

A second benefit is suggested by the impact that these costs can incur to so-called 'marginal proliferators.' Iraq has shown that countries with the intent and resources to pursue special weapons programs in the face of export controls will probably find suppliers for the required technology and equipment. However, *as the diplomatic and economic penalties associated with violating these regimes increase, countries can be persuaded to abandon their efforts.* As Senator Glenn suggested, "...small countries that are putting their scarce resources over into [nuclear weapons programs] ... could be encouraged through sanctions maybe to stay away from [these efforts]."[39] Argentina's reported abandonment of the Condor 2 program can be seen as proof of the effect that diplomatic and economic pressure can have.[40] Also, it has been suggested that vigorous opposition and sanctions in the early years of the alleged Israel nuclear program may have bolstered its internal opponents and enabled them to prevail.[41]

A third benefit stems from the fact that these *export control regimes, as a reflection of national and international policy, are useful mechanisms for getting countries' special weapons programs onto the political agenda of the supplier states.* Consequently, these regimes then provide a political and legal framework within which these countries can deal with these programs. For example, the

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39 Ibid., p. 12.

40 See, for example, H. Porteous, "Argentina cancels Condor 2 missile," *Jane's Defence Weekly*, 8 June 1991, p. 948.

41 According to Seymour Hersh, David Ben Gurion met repeated resistance within the Israeli cabinet during the early years of the nuclear program. Much of this resistance was based on the financial drain that the program imposed on what was perceived as a more immediate need for conventional weaponry. Some opponents also argued on the basis of the immorality of nuclear weapons. Had Israel faced substantial external political and economic penalties during this early period, it is conceivable that the nuclear program could have been defeated by these opponents. See S. Hersh, *The Sampson Option – Israel's Nuclear Arsenal and American Foreign Policy*, (New York: Random House, 1991), pp. 59-70.

recent experience of the North Korean vessel suspected of shipping Scud missiles and production equipment to Iran and Syria was used to illustrate the need for expanding the MTCR beyond the current list of signatories.

And, lastly, these regimes have important intelligence benefits because they provide an important structure to the problem of monitoring a country's activities. For example, former CIA Director William Webster stated that

> "if a country refuses to join a nuclear control regime, we have a clear signal that we should focus additional attention on its nuclear development programs, and we certainly do. From my perspective, the Non-Proliferation Treaty and the activities of the International Atomic Energy Agency help us use our intelligence resources more effectively to track nuclear developments."[42]

Thus, *by providing potential indications of intent and warning, export control regimes and their inspection and data notification activities, can serve a valuable intelligence function.*

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[42] See *Nuclear and Missile Proliferation*, p. 11.

IV. INTELLIGENCE IMPLICATIONS

So far, this paper has discussed the potential implications for national and international technology control regimes which the Iraq experience has highlighted. This section will now discuss the foundation of the nonproliferation framework referred to earlier – intelligence. Intelligence in this context primarily involves three missions: (1) *warning* that a country is either attempting or has succeeded in developing a special weapons program; (2) determining its *intentions* or the perceived goals of the program; and (3) assessing the potential *capabilities* of the weapons systems being developed under the program. Warning, intentions, and capabilities – essentially this is the process of discovery that either technology controls have failed, or that there is a threat of failure.

With this in mind, the Iraq experience has highlighted three factors which may have important implications for the U.S. intelligence community and international nonproliferation efforts. These include the impact of rapid change in the former Soviet Union, and the effect that this has on the IC's ability to respond to the emergence of special weapons proliferation as a high priority issue. Moreover, the difficulty of monitoring the proliferation problem is increased because of the evolving nature of these programs. An important consequence of this evolution is the increasing requirement for operational data on Third World forces as they mature and become fully operational. Finally, the Iraq experience illustrates several potential new and expanded roles that the U.S. IC may play in future nonproliferation efforts.

INTELLIGENCE IN THE WAKE OF THE SOVIET DISSOLUTION

For half a century, the U.S. Intelligence Community (IC) has focused much of its personnel and technical resources against what was the principal threat to the national security of the United States – the Soviet Union. From an intelligence perspective, this problem had over-riding priority over most other issues. According to one former CIA analyst, this over-riding concern about the Soviet Union also tended to lead analysts charged with other important intelligence problems, such as Third World developments and weapons proliferation, to focus on potential Soviet involvement in these problem areas.[43]

Consequently, with a large proportion of its resources dedicated to this problem, the IC was presumably able to develop a comprehensive understanding of the political, military, economic, and societal developments in the Soviet Union. With this level of resources, there were more opportunities for focusing

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[43] See P. Scalingi, "U.S. intelligence in an age of uncertainty: Refocusing to meet the challenge," *The Washington Quarterly*, Winter 1992, p. 148.

collection and analysis on specific military and political problems, such as the capabilities and operations of a particular weapons system. Ultimately this level of dedication enabled the IC to come to a greater understanding of various aspects of the Soviet Union.

In the wake of the dissolution of the Soviet Union and the emergence of pressing new issues on the intelligence agenda, however, the IC has been forced to adapt to a changing and uncertain world.[44] The process of change within the IC is reportedly underway today as resources are shifted to reflect new priorities.[45] As this process occurs, however, it is important to point out two limitations in the IC's near-term ability to come to grips with these priorities. First, contrary to some reports, the Soviet Union has not gone away as an intelligence priority. The collection of former Soviet republics, particularly those still possessing nuclear weapons, still pose a grave threat to the national security of the United States and, thus, will mandate continued intelligence attention for years to come. What has changed, however, is the relative priority of other issues, such as weapons proliferation. Thus, what is occurring is likely to be not a reduction in U.S. intelligence requirements but an increase instead.

Second, the process of reorienting these intelligence assets is not likely to be an easy or simple task and is not likely to produce an immediate level of intelligence understanding comparable to that which existed for the former Soviet Union. *Lacking the level of detailed attention that the IC was able to afford Soviet issues over the last four decades, it will take time to gain a comparable understanding of the political, military, and economic issues that have risen in priority over the last few years.* Moreover, in some cases, we may never achieve this level of comparable understanding.

Complicating this task will be the fluidity of these problems in terms of their priority. For example, only 5 years ago, congressional testimony and media attention on ballistic missile nonproliferation issues was almost entirely focused on India, Brazil, Israel, and the Condor program (with most of the emphasis on Argentina's participation). Where Iraq was mentioned, it was usually only in the context of a list of countries fielding Soviet-supplied Scuds. Of course 5 years later, we now realize that during this time period Iraq was heavily engaged in a

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[44] See recent testimony by CIA Director Gates on proposed changes to the IC, particularly *Statement on Change in CIA and the Intelligence Community*, 1 April 1992. See also Scalingi for a useful discussion of the key issues facing the IC in the wake of the Soviet dissolution.

[45] CIA Director Gates recently refuted criticism that the IC has been too focused on the former Soviet Union during an era of great change. Specifically, he stated that the IC has been shifting its resources to cover other issue areas for the last several years. He stated that in 1980 – the height of the Cold War – only 58% of IC resources were devoted to the Soviet Union. This number has since dropped to 50% by FY90, and will be only 34% for the Commonwealth of Independent States in the future. See *Statement on Change in CIA and the Intelligence Community*, pp. 33-34.

comprehensive special weapons program, and is today a top priority on the nonproliferation agenda. Therefore, the question of which country or program poses the most significant threat to U.S. interests is not a simple one to answer, and is more than likely to change rapidly in the coming years.

INTELLIGENCE REQUIREMENTS FOR EVOLVING PROBLEMS

Not only has the nature of the overall problem changed dramatically for the Intelligence Community, but so too has the nature of the intelligence requirements for specific countries as their programs evolve. Specifically, *the IC will be increasingly tasked to provide information on the operation of these forces as they mature and are deployed into these countries' armed forces and defense strategies*. This highlights the differences that exist between monitoring a program as a proliferation problem and monitoring in support of potential military operations. To a large extent, these are different problems and pose different intelligence requirements.

On the one hand, monitoring proliferation requires first an understanding of whether a country either is or intends to engage in a special weapons program. From here, questions of supply networks, types of systems being sought, facilities and other states or actors that are involved, and some level of understanding as to the systems' intended capabilities are paramount intelligence concerns.

On the other hand, as these programs mature and become operational, other issues can increase in importance, particularly if they are seen as potential threats to the United States or its allies. At this point, intelligence also needs to support potential warfighting strategies. Key issues here, in terms of a ballistic missile system, include its mode of operation, the level of training for the force, where and how the system is likely to be employed, and the force's operational doctrine and tactics.[46] Desert Storm demonstrated the difficulty of accurately forecasting future adversaries. A frequently stated 'lesson' from Desert Storm is that the 'next Iraq' is not likely to give the United States a 5 1/2 month mobilization period prior to hostilities. Therefore, it is imperative to develop a thorough understanding of the military-operational aspects of these programs.[47]

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[46] Soviet commentators attributed the relative lack of success of Coalition offensive actions against the mobile Scud units to both the effectiveness of Iraqi operations and to the suggestion that "'...the U.S. intelligence ... underestimated the possibilities for the secret deployment of Scuds' and was forced to revise their initial estimates of damage inflicted on Iraqi assets." See "Iraqi Military Potential 'Far From' Destroyed," Moscow TASS (in English) 2106 GMT 22 January 1991, printed in FBIS-SOW-91-015, 23 January 1991, p. 16.

[47] For a good argument in favor of this point, see Dunn, pp. 62-63. The author suggests that "a new emphasis on understanding the 'back-end' of nuclear weapon organization, safety and security, decision-making, deployments, alert procedures and doctrine in new nuclear powers should now be added. This complements the more traditional 'front-end' concentration on tracking proliferation

NEW CHALLENGES FOR INTELLIGENCE SUPPORT

In recent congressional testimony, Dr. Hans Blix, Director General of the IAEA, made the following point regarding the value of intelligence to the Iraqi inspection effort:

> "What was it that enabled the inspectors in the course of 5 months to find what had not been uncovered in 10 years before? One single answer: Intelligence, information."[48]

The unprecedented willingness of national governments to provide the UNSCOM and IAEA with relevant intelligence information has been critical to the inspector's success in uncovering Iraq's weapons programs in the face of significant deception activities.

Intelligence information provided by national governments has helped the UNSCOM and IAEA to reconstruct a picture of Iraq's various weapons programs and to identify its network of foreign suppliers. The provision of timely intelligence by friendly governments has guided several U.N. teams to important inspection targets. In one case, the U.N. inspectors obtained photographic evidence of Iraqi efforts to hide calutron equipment used for enriching uranium. In another well-known case, a UNSCOM/IAEA inspection team undertook a highly successful document raid on Iraq's nuclear program headquarters that produced solid evidence of its weaponization activities.[49]

The Iraqi inspection experience has highlighted the benefits stemming from unprecedented cooperation between national intelligence organizations and multinational institutions. The United States is providing various types of support for UNSCOM activities, including "U-2 surveillance flights, the provision of intelligence, and expert inspectors."[50] Other governments have also made important contributions in this area. For example, Germany helped U.N.

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problem countries' pursuit of the materials, facilities and know-how to build a first nuclear weapon, as well as additional emphasis on 'upstream' tracking of nuclear programs in countries not now at the top of the proliferation watch-lists." The author goes on to suggest that human intelligence is likely to play a greater role in ascertaining this 'back-end' intelligence.

48 *Nuclear Proliferation: Learning from the Iraq Experience*, p. 29.

49 Interviews with UNSCOM and IAEA inspectors. For descriptions of the successful U.N. inspection at Falluja, where the inspectors caught a convoy moving calutron equipment, and of the seizure of key documents in a raid at the Iraqi nuclear headquarters, see Zorpette, pp. 21, 24; and Hedges and Cary, pp. 36-38.

50 "Letter to Congressional Leaders on Iraq's Compliance with United Nations Security Council Resolutions," dated 16 March 1992, *Weekly Compilation of Presidential Documents*, 23 March 1992, p. 495.

officials to track down the foreign sources of equipment and expertise involved with Iraq's centrifuges enrichment program.[51]

The benefits of sharing national intelligence information with international organizations is evident from the Iraqi experience in terms of more effective inspections against a country of great concern to many national governments.[52] But each side in this novel arrangement entered with clear reservations. National intelligence organizations are concerned about risking the exposure of their sources and methods when providing sensitive information to international organizations. On the other hand, U.N. officials are very sensitive about appearing to engage in intelligence collection and analysis.[53] Thus, whether the Iraqi experience in intelligence support proves to be unique probably depends on whether a balance can be reached that will accommodate the concerns of each side.

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[51] Ibid., p. 495.

[52] On the broader arms control implications of this intelligence-sharing arrangement, see M. Krepon, "Iraq inspections offer lessons to U.S.," *Defense News*, 7 October 1991, p. 23.

[53] In comparison, IAEA Director Hans Blix has been more outspoken about the need for his agency to have greater access to sensitive information that national governments could provide on both Iraq and other potential nuclear proliferants. He has proposed creating a small unit within his office at the IAEA to "evaluate intelligence information that may be given to us," as a basis for requesting a special inspection. See *Nuclear Proliferation: Learning from the Iraq Experience*, p. 31; and Interview, "IAEA Director Hans Blix: Keeping an Eye on a Nuclear World," *Arms Control Today*, November 1991, p. 4.

V. DISARMAMENT ENFORCEMENT IMPLICATIONS

The U.N. inspections in Iraq have produced a rich experience that is possibly relevant to similar situations where arms control or peacekeeping inspectors must operate in an uncooperative environment. The inspections conducted in Iraq differ significantly from the more familiar IAEA or INF Treaty inspections where the inspected country usually is a willing partner in the verification process. In comparison, the UNSCOM and IAEA inspections offer real world insights on the factors that contribute to success in the face of active resistance by a host country. After a brief description of the U.N. disarmament mandate concerning Iraq, this section analyzes the insights gained from the U.N. disarmament enforcement activities in Iraq in terms of inspection operations effectiveness, the role of technical support capabilities, and the nature of inspection team composition.

U.N. ENFORCEMENT ACTIVITIES IN IRAQ

In April 1991 the U.N. Special Commission was established by the Security Council as its executive agent for supervising the dismantling and elimination of Iraq's capability for producing and deploying weapons of mass destruction. The UNSCOM derives its legal authority from a series of U.N. Security Council resolutions (# 687, 707, and 715) that charge it, along with the IAEA, to implement a three-phase disarmament process consisting of:

- Inspecting and surveying Iraqi capabilities and facilities in the nuclear, chemical, biological, and ballistic missile fields to map out the full nature of Iraqi weapon activities (phase I);

- Disposing of these Iraqi weapons and their associated equipment and facilities through destruction, removal, or rendering harmless (phase II); and

- Establishing a long-term monitoring regime to ensure ongoing Iraqi compliance with the Security Council's prohibitions on its weapon system activities (phase III).[54]

To perform these missions, the U.N.-sponsored teams have undertaken more than 35 inspections of Iraqi facilities and equipment.[55] These continuing, highly

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[54] "Letter dated 24 October 1991 from the Executive Chairman of the Special Commission ...," in the U.N. Security Council document S/23165, pp. 4 and 16-17.

[55] Operations support for the inspections comes from the UNSCOM office at the United Nations with most of the logistics being handled by a field office in Bahrain and a support office in Baghdad.

intrusive inspections are necessary for verifying thc accuracy of official Iraqi declarations on weapon stockpiles and relevant facilities, and for discovering facilities that Iraq has failed to declare.

INSPECTION OPERATION EFFECTIVENESS

Compared with other types of arms control operations, such as the IAEA safeguard inspections, the disarmament process in Iraq has often featured a distinctly "cat-and-mouse" flavor as the Iraqis have tried several ways to undermine the disarmament enforcement process. Despite Saddam Hussein's begrudging acceptance of the Gulf War cease-fire conditions specified in resolution no. 687, the Iraqis used the following tactics in trying to undermine the disarmament enforcement process:

- Political non-recognition of the U.N. mandate,
- Manipulation of threat perceptions,
- Extensive deception efforts.

In the first case, the Iraqi regime has resisted the disarmament enforcement process by not recognizing certain Security Council resolutions (#707 and 717) that expanded the inspection roles of the UNSCOM and IAEA, and provided authorization for a long-term monitoring plan to verify Iraqi compliance.[56] This has led the Iraqis to withhold information that the inspectors need to map out the various Iraqi weapon programs that are slated for elimination.

Second, Iraq has tried to undermine the disarmament process through pronouncements or actions that threaten to put U.N. inspectors in harm's way. These threats have ranged from official Iraqi warnings on the risks associated with certain enforcement activities to more tangible demonstrations of the personal risks being assumed by the inspection personnel.[57] Although the ongoing U.N. inspections are somewhat reminiscent of the unrestricted Allied inspections of Germany under the Versailles Treaty, an important distinction

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[56] See, *Arms Control Today* (April 1992), p. 6. The Iraqis have also tried to limit the impact of the disarmament enforcement process by arguing for favorable interpretations of the U.N. resolutions. Accepting Iraq's interpretations would spare certain facilities and types of dual-use equipment that the UNSCOM and IAEA have concluded should be destroyed.

[57] The Iraqis have tried various intimidation tactics including: holding a nuclear inspection team hostage in a Baghdad parking lot for 97 hours, allowing CW inspectors to be surrounded and jostled by an "uncontrolled" crowd, firing warning shots at inspectors photographing an illegal convoy, and making official warnings about the risks of "uncoordinated" U.N. helicopter flights. See U.N. Security Council document S/23165, pp. 7-8; and "Letter . . . on Iraq's Compliance with U.N. Security Council Resolutions, " *Weekly Compilation of Presidential Documents*, 23 March 1992, p. 495.

exists: Iraq was militarily defeated in Desert Storm but not disarmed as the Germans were after World War I.

Third, Iraq has also used various deception practices in trying to undermine the U.N. inspections. These practices have included misleading declarations of weapon inventories and facilities, a variety of concealment measures to make the tasks of UNSCOM and IAEA inspectors more difficult, and preemptive destruction of key pieces of equipment and facilities.[58]

To overcome these obstacles created by the Iraqis, the U.N. inspection teams have adopted some rather extraordinary practices in carrying out their missions, including the following operational modalities:

- anywhere, anytime
- minimal notice
- no explanation
- complete access
- full right to record activity and collect documentation, and
- self-sufficiency in inspection team activities.

These practices enabled the UNSCOM and IAEA teams to take advantage of the important intelligence information provided by friendly governments in searching out undisclosed weapon facilities and defeating various Iraqi attempts to hide weapons-related equipment and documentation from the inspectors.

The effectiveness of the UNSCOM and IAEA inspections in surmounting the Iraqi resistance and deception efforts was proven in at least two well-known cases. The first occurred in June 1991 when the second IAEA inspection mission succeeded in locating where the Iraqis were hiding their disassembled calutron components. Using information from a friendly government based on national technical means (NTM), the IAEA inspectors undertook a no-notice inspection of the suspect hide site, the military base at Falluja. Even though they were denied access to the facility, the IAEA inspectors demonstrated substantial

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[58] These included removing and hiding equipment from key facilities, preemptively destroying or burying equipment before U.N. inspectors can inventory it, and even keeping item moving around during inspections. Some key buildings associated with the nuclear program were razed and tell-tale structures covered with rubbles or concrete. The Iraqis have also removed names plates from foreign-supplied machines to keep U.N. inspectors from easily determining their origins. Interviews with UNSCOM and IAEA inspectors; and *Nuclear Proliferation: Learning from the Iraq Experience*, pp. 19-21.

initiative by photographing the nuclear equipment being carried away by trucks departing from the site. The photographs offer indisputable evidence of Iraq's undeclared calutron program for enriching uranium, as well as the extent of Iraq's deception activities.[59]

A second, even more publicized, case involves the U.N. inspection raids on two headquarters buildings in Baghdad during September 1991. The inspectors were tipped off that a large amount of documentation on Iraq's clandestine nuclear program was located at these sites. The raids, that were carefully targeted and executed by the U.N. inspectors, yielded over 45,000 pages of documentation. Among the most important information in the document cache was "smoking gun" evidence of Iraq's weaponization efforts for developing an implosion type of nuclear weapon.[60]

Both cases highlight the possible payoffs of conducting "anytime, anywhere" inspections without being obligated to give the other side advance notice of the inspection target. Each episode demonstrates that by combining unfettered access with timely intelligence, as provided by friendly national governments, the U.N. inspectors were able to catch the other side off guard and expose prohibited activities.[61] These results run counter to the conventional wisdom that the chances of discovering hard evidence of prohibited activities is minimal given the inspected party's opportunities to obstruct the inspectors.

Of course, some special circumstances were at work here. One was the highly intrusive disarmament enforcement regime that the U.N. Security Council imposed on Iraq in the wake of its military defeat in the Gulf War. Another factor was that the Security Council provided unanimous backing for the U.N. inspections in overcoming continuing Iraqi resistance. Whenever the Iraqis attempted to stall an inspection, the Security Council responded promptly by bringing to bear substantial diplomatic pressure on Iraq to comply with the inspectors' requests. Equally important, however, the Security Council's resolve was backed by U.S. determination to see that Iraq complied fully with the cease-fire resolutions including the weapons disarmament enforcement process. In

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59 The official account of the inspection results is contained in U.N. Security Council document S/22788 (15 July 1991), pp. 9, 13. Also see *Nuclear Proliferation: Learning from the Iraq Experience*, pp. 15, 18, 30; Zorpette, p. 24; Hedges and Cary, pp. 36-37; and C. Murphy, "Iraqis Fire Shots Near U.N. Team," *Washington Post*, 29 June 1991.

60 U.N. Security Council document S/23122 (8 October 1991), pp. 3-6; and the testimony of Dr. David Kay, the chief inspector for this IAEA mission, in *Nuclear Proliferation: Learning from the Iraq Experience*, pp. 16-19; Albright and Hibbs (January/February 1992), pp. 30-32; and C Norman, "Iraq's Bomb Program: A Smoking Gun Emerges," *Science*, 1 November 1991, pp. 644-645.

61 Interviews with UNSCOM and IAEA inspectors; *Nuclear Proliferation: Learning from the Iraq Experience*, pp. 17 and 23; and the SMU conference abstracts.

response to episodes of Iraqi recalcitrance, U.S. officials have warned Iraq that sufficient Coalition military forces are stationed in the Persian Gulf to make the use of military force a credible option of last resort for eliminating residual Iraqi weapon facilities if noncompliance problem are not promptly resolved.[62]

Despite the vigorous Iraqi efforts to mislead and constrain the U.N. disarmament enforcement operations, the inspection teams appear to have been relatively successful in mapping out the key features of the Iraqi weapon acquisition programs. Nonetheless, given Iraq's unwillingness to make available all relevant documentation on their weapon development programs, several important questions still remain. These include whether an underground plutonium reactor might exist, the possibility that a pilot centrifuge cascade for uranium enrichment was constructed, questions about the exact nature of Iraq's biological weapons work, and the likelihood that the Iraqis failed to declare a significant numbers of ballistic missiles.[63]

THE ROLE OF TECHNICAL SUPPORT CAPABILITIES

The proactive U.N. inspections in Iraq provide some practical insights on the benefits of having certain types technical support organic to the inspection teams. These technical and logistical capabilities primarily involved transportation, navigation, communications, and on-site sampling. The self-sufficiency of the U.N. inspection teams in terms of having their own vehicles made it much more difficult for the Iraqis to impede or channel U.N. inspection operations. The inspection teams also made good use of portable global positioning systems to ensure that they were inspecting the right location. Without such capabilities for independent movement and navigation, the U.N. inspectors would have been in the dubious position of depending on the Iraqis to transport them to suspected sites.

For communications the UNSCOM and IAEA teams used portable radios to maintain contact among subgroups of inspectors. They also had available a

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[62] Saddam Hussein appears to have deliberately engaged in a continuing test of wills concerning the U.N. disarmament enforcement process. A pattern developed over time whereby increasing Iraqi intransigence in the face of U.N. inspection activities would often stimulate a series of threatening U.S. and Coalition statements and military activity , and then be followed by renewed Iraqi acquiescence. For example, see A. Devroy and J. Lancaster, "Bush Threatens to Send Jets to Back Up Iraq Inspections," *Washington Post*, 19 September 1991, p. A1; J. Goshko, "Iraq Says It Will Permit U.N. Flights," *Washington Post*, 23 September 1991, p. A1; A. McDaniel, et. al., "Playing Chicken in Iraq," *Newsweek*, 30 September 1991, pp. 38-39; J. Goshko, "Security Council Warns Iraqis to Halt Cease-Fire Violations," *Washington Post*, 13 March 1992, p. A1, and P. Tyler, "U.S. Carrier Enters Gulf as Iraqis and U.N. Spar Over Compliance," *New York Times*, 14 March 1992.

[63] *Arms Control Today* (April 1992), pp 6-8.

portable satellite telephone system for long-distance communications.[64] Maintaining connectivity with UNSCOM headquarters in New York proved vital to the success of the U.N. inspection operations. It gave the inspector teams a mechanism for making timely appeals to the U.N. Security Council when Iraqi stalling tactics occurred, and it served as a vital communications link in potentially risky confrontations with the Iraqis, such as when the U.N. inspectors were forcibly detained during the document raids in September 1991.

Various types of equipment and sensors were employed by the UNSCOM and IAEA in the course of their on-site inspections. The U.N. teams generally made film and voice recordings of their activities and their frequent protests with Iraqi officials impeding their access during inspections. Seals were often placed on Iraqi equipment and storage areas to provide indications of any tampering between the inspectors' visits.

Often the equipment varied with the type of inspection. For example, sample wipes were extensively taken at Iraqi facilities to identify declared nuclear materials and to look for residual traces of undeclared substances. A portable acoustic resonance detection system and other types of CW analysis equipment was used by the UNSCOM inspection teams. Inspectors also made use of protective and decontamination equipment.

The national governments were fairly responsive in providing the UNSCOM and IAEA teams with off-the-shelf equipment as needed for the inspections. But the inspections also revealed some problems in this area. For example, the inspectors were unable to obtain a ground-penetrating radar system. This type of sensor was needed for determining whether the Iraqis were concealing prohibited materials in underground structures or in hidden rooms at Iraqi facilities and to detect buried pieces of equipment. In addition, several inspectors have identified the need for an on-site sample analysis capability for nuclear materials. Having timely sampling results, even at a crude level of analysis, could be a potentially invaluable capability when conducting proactive inspections that allow for immediate confirmation and follow-up of any significant discovery.[65]

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[64] Zorpette, p. 63.

[65] Ensuring timely and reliable analysis of nuclear samples has been a problem associated with the Iraqi inspections. Obtaining sample analysis from high-tech IAEA or U.S. laboratories typically involves a lengthy process. In addition, there is evidence that a sample taken by an IAEA team at Iraq's Tuwaitha complex that was judged to be weapons-grade uranium may have been contaminated in the sample analysis process. Ibid., pp. 64-65.

INSPECTION TEAM COMPOSITION

The UNSCOM has worked closely with the IAEA, which was assigned by the Security Council the lead role in dealing with Iraq's nuclear program. Although the small UNSCOM secretariat draws heavily on U.N. personnel, much of the material and personnel support for the UNSCOM inspections comes from various national governments.[66] In particular, inspectors with specific weapon expertise are often provided by countries such as the United States, United Kingdom, France, Canada, Germany, and Russia.

The UNSCOM and IAEA inspections have consisted of large teams, with as many as 45 individuals in some cases. The inspections have been multinational operations with personnel from more than a dozen countries serving on a particular mission. The inspections have typically run from about 10 days to 2 weeks, excluding the time needed for making team preparations and transporting the inspectors to Baghdad. A premium was placed on selecting individuals in good physical condition given the potential rigors of conducting inspections in an antagonistic environment and Iraq's hot weather.[67]

Highly qualified experts on nuclear, ballistic missile, chemical, or biological weapons account for a substantial proportion of the team members. These experts are temporarily made available by various national governments from their scientific and military establishments. Several participants in the Iraqi inspections have emphasized the invaluable contributions of such national experts with their experience in weapons development and operations, particularly in terms of identifying Iraqi equipment and facilities with weapon applications. The nuclear inspections especially benefited from the availability of U.S. weapons laboratory experts who not only were very knowledgeable about modern nuclear weapon systems but also possessed enough historical perspective to confidently identify the methods and technologies that the Iraqis were using to develop a first generation nuclear weapon.

THE CHALLENGE OF LONG-TERM ENFORCEMENT

Despite its near-term success, the staying power of the U.N. enforcement regime over the longer run is open to question. The continuing U.N.

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[66] U.N. Security Council document S/23165, pp. 12, 34-36.

[67] In addition to the general stress of working in an adversarial environment, U.N. personnel routinely assumed personal risks when visiting bomb-damaged Iraqi facilities where unexploded ordnance or leaking CW munitions were present. Shoddy Iraqi safety practices at their Al Muthanna CW site added to the risks. In one instance, when a supposedly unfilled 122-mm rocket was being destroyed, the warhead burst and an Iraqi working with U.N. inspectors was exposed to nerve agent. See U.N. Security Council document S/23165, pp. 26, 29; and B. Schoenfeld, "Despite Bullying from Saddam, U.N. Teams Making Progress," *Defense Week*, 30 September 1991, p. 9.

inspections have effectively exposed and disrupted the Iraqi weapon programs for the time being. But there is no guarantee that Saddam Hussein will not resume Iraq's clandestine programs if the inspections cease. In fact, the enforced U.N. disarmament process is mostly focused on treating the symptoms of the weapons proliferation problem rather than its source. Although the U.N. Security Council has authorized the UNSCOM to implement a program to monitor Iraq indefinitely, some type of political solution is undoubtedly needed to contain the Iraqi weapon proliferation problem over the longer run.[68] In the meantime, the very intrusive U.N. monitoring regime probably can be counted on to raise the political and financial costs of any attempt to resurrect Iraq's programs for weapons of mass destruction and to provide important indications of any changes in Iraqi intentions.

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[68] The long-term plan for monitoring Iraqi compliance with U.N. Security resolution 687 that prohibits certain weapon-related activities is contained in U.N. Security Council document no. S/22871/Rev. 1 (2 October 1991). The plan envisions monitoring and verifying activities occurring at both military and civilian sites to ensure that Iraq is not violating the Security Council's restrictions.

VI. CONCLUDING OBSERVATIONS

This paper has addressed a number of factors that contributed to Iraq's ability to build an impressive and complex development and production capability for nuclear, chemical, and, possibly, biological weapons, and including the missile and long-range artillery systems to deliver them on target. In so doing, key implications for future technology control regimes, intelligence efforts, and enforcement mechanisms have been highlighted. In this summary, we will review these key implications and address the question raised in the paper's title on the uniqueness of the Iraqi experience versus the ability of the United States and its allies to apply these lessons toward future nonproliferation efforts.

IMPLICATIONS FOR CURRENT TECHNOLOGY CONTROL REGIMES

To a large extent, Desert Storm provided an ominous 'wakeup call' to the industrialized nations regarding the increasingly widespread availability of special weapons technology to potential Third World belligerents. Clearly, weapons proliferation is not a new problem. What is new, however, is the increased sophistication that countries like Iraq have demonstrated, and the growing diversity of suppliers that are now available. In this regard, the implications raised here extend beyond the Iraq case, and highlight key weaknesses in technology control regimes limited to the Western industrialized states and Japan. The prominent role that Brazil, Argentina, and Egypt allegedly played in Iraq's weapons programs highlight the need to expand the political and economic framework of these regimes to include this new class of weapons supplier.

In so doing, it will also be imperative to recognize the need for a much greater level of coordination, from the highest policy levels down to technical issues regarding what should be controlled and transferred. Past political and bureaucratic divisiveness, both within the U.S. government and between the United States and other supplier nations, probably played a role in Iraq's ability to develop its weapons programs. Reportedly, this situation is improving, and the political and military cohesiveness demonstrated by the Coalition during Desert Shield and Desert Storm is cause for hope. However, the unity of purpose demonstrated during crisis and war needs to be carried over into peacetime nonproliferation efforts so that other countries can be dissuaded or prevented from achieving what Iraq nearly did. Again, these issues are not unique to the Iraqi experience but, rather, are key lessons that need to be applied to other nonproliferation matters.

Finally, while recognizing the key failures and limitations of current nonproliferation efforts, it is also important to recognize the positive contributions that these regimes have and will continue to make. Most notably, the fact that Iraq required a complex covert acquisition network is an illustration of the benefits even an imperfect technology control regimes can bring about by increasing the costs, risks, and time involved in special weapons programs. Moreover, these regimes provide a framework for political action, and a context and focus for intelligence collection efforts. Again, the Iraq experience is not unique in these areas, but does serve to highlight their continued relevance.

INTELLIGENCE IMPLICATIONS

In many respects, Iraq has provided a benchmark for future intelligence requirements in the wake of the dissolution of the Soviet Union. The Intelligence Community is already in the process of reorienting its human and technical resources; however, that this process will take time. Essentially, the IC is moving away from a monitoring problem that had over-riding priority for the last four decades, and into an era of numerous problem areas with more fluid prioriti7 tion. *Lacking the level of detailed attention that the IC was able to afford Soviet issues over the last four decades, it will take time to gain a comparable understanding of the political, military, and economic issues that have risen in priority over the last few years.*

Not only has the nature of the overall problem changed dramatically for the Intelligence Community, but so too has the nature of the intelligence requirements for specific countries as their programs evolve. Specifically, *as Third World weapons programs mature, the intelligence requirements will correspondingly need to shift away from purely proliferation-oriented issues and towards greater operational intelligence that may be required to support potential future military actions.* Desert Storm was unique in the sense that Saddam provided 5 1/2 months for the Coalition to get forces in place and to gather intelligence. Because the next adversary is not likely to allow this luxury, and because it is difficult to judge with certainty who that adversary may be, it is imperative to gain a full understanding of not only what systems that potential threat countries have or are developing, but also how and where they will be employed.

Finally, the success of UNSCOM and IAEA inspections in Iraq illustrate the value of the unprecedented level of intelligence support that the United States and other governments have provided. This has been a relatively unique experience, and may be difficult to repeat in future nonproliferation efforts. Of particular concern in this area is the hesitance that national intelligence agencies will have in sharing information, as well as, possibly, the reluctance of international institutions like the UNSCOM to play an active role. However, the lesson from Iraq is that special weapons proliferation is not simply a bilateral or regional problem - it can have widespread implications - and warrants the coordinated efforts of the United States and its allies. Thus, whether the international intelligence support provided for the Iraqi problem remains a unique experience is currently unknown. But the potential benefits of coordinated intelligence support in cases like Iraq are clear.

DISARMAMENT ENFORCEMENT IMPLICATIONS

In addition to intelligence support, the U.N.-sponsored inspections have also benefited from the unanimous diplomatic support from the U.N. Security Council and the threatened use of Coalition military force to overcome Iraqi intransigence. Of particular interest to future nonproliferation efforts, however, has been the success of the highly intrusive inspection regime that has been operated within Iraq. With 'anytime, anywhere' inspection rights and no pre-notification, UNSCOM and IAEA teams have been able to maximize the benefits from the intelligence and political support provided to their effort. However, given the principal of reciprocity that would be applied to most other nonproliferation efforts short of warfare, it is debatable which of the current Coalition members would agree to comparable inspection provisions within their own borders. Thus, in the absence of the military and political context that has shaped the Iraqi experience, it is unclear whether the lessons from these inspections will lead towards similar arrangements in future nonproliferation efforts, such as the Chemical Weapons Convention or an enhanced MTCR.

However, the inspections did highlight the utility of several more tactical areas that can probably be applied to future efforts. First, this experience illustrated the advantages of inspection teams that are self-supported with logistics and communications. This provides a level of flexibility and independence that UNSCOM and IAEA officials have used to great advantage in Iraq. Also, deploying reliable communications equipment with the inspectors has greatly improved their efficiency and authority by providing the ability to bring direct U.N. decision-making authority in situations of Iraqi intransigence. Finally, the inspections have also highlighted the need for greater on-site technical analysis support, such as a capability for on-site sample analysis to support nuclear inspections.

Lastly, the Iraqi inspections have highlighted the benefit of fielding teams with the right amount of technical expertise in relevant weapons areas, including knowledge of the equipment and facilities used in developing both modern and first-generation weapons of mass destruction. In each of these last few cases, there seems to be few compelling reasons why these lessons need be unique to Iraq, and should be applicable to future inspection regimes under the CWC, MTCR, or IAEA mandates.

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SESSION V

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Chairman
R. Wagner
Kaman Sciences Corporation

Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

The Verification Equation

C. DiMaggio
System Planning Corporation

Prepared for:
Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

THE VERIFICATION EQUATION

Cosmo DiMaggio System Planning Corporation

INTRODUCTION

Prior to the INF Treaty, the verification of arms control agreements between the superpowers was essentially satisfied through monitoring by National Technical Means. As such, the contribution of arms control to reductions in the costs of the arms race and crisis stability were limited by NTM monitoring and verification capabilities. With the advent of onsite inspections, these limitations were somewhat lessened. Moreover, verification has become a "tool" in its own right for strengthening stability through confidence building.

In light of very recent world events, the future role for verification is uncertain. After all, verification of arms control agreements is less critical the less antagonism and more trust there is among the players. In fact, there is no formal verification of the unilateral dismantlement and destruction of nuclear and chemical arms that is in process today. Nevertheless, there is still a role for verification to play in continuing to build confidence. Moreover, there is still a need for monitoring compliance with current and possible future multilateral agreements where trust has not been established in all cases, and where the actors and motivations are subject to change, perhaps rapidly.

So how does one define verification requirements in such an uncertain world? And, given that not all requirements can be met by visual inspection, how do these verification requirements get translated into a research and development program aimed at satisfying them?

THE EQUATION

An accepted premise in the United States government over the last decade or more has been that no arms control agreement would be in the U.S. interest unless it could be fully verified. During this period, both arms control policy and related research and development programs were based on this "all or nothing" philosophy. Consequently, verification research and development programs were tasked with providing answers to two simple questions: 1) What can be verified?, and 2) How much will it cost? Very little, if any, rigor and coordination was applied to assess the relative benefits, costs, and risks of the potential agreements in concert with their associated verification regimes. Moreover, in most cases, research and development planning horizons were extremely short. It was not unusual for a verification requirement to materialize during the course of the endgame negotiations.

Financial constraints, political shifts, and concern over the proliferation of weapons, particularly those of mass destruction, have forced a reassessment of that verification strategy. The current environment dictates a more reasoned approach to verification whereby decisions on regimes and associated research and development programs are based on objective assessments of their potential benefits, costs, and risks.

The factors that must be considered in such assessments are not new. However, a framework for addressing them appears to be lacking. Thus, for the sake of providing a strawman for discussion, I will represent these factors as elements of a cost-benefit equation. While I recognize that it is impossible to quantify all of these factors, I also know that that is not necessary in order to use the equation as a tool to aid decision making. The important thing is to have a framework that allows one to make decisions based upon the best available information about all of the pertinent factors.

On the benefit side of the equation the factors are synonymous with the potential objectives of a verification regime. They include:

- The contribution of the prospective verification technique or measure to confidence in the other party's compliance
- The ability of the measure to deter cheating (through spoofing or circumvention)
- Confidence building for the sake of improving stability, and
- Providing a basis for bringing international pressures to bear on deviant behavior.

While there is a certain degree of interdependence among these factors, the differences among them are quite significant for deciding on the appropriate verification regime. In the case of ensuring compliance, the primary objective is to attain unambiguous proof that the limits of an agreement are being adhered to. The ability to deter cheating, on the other hand, focuses on the ability to increase the costs and risks of cheating to the other party. This differs again from confidence building, which has more to do with understanding the capabilities and intentions of the other side, and providing a basis for international sanctions, which requires making a noncompliance case from evidence that can be shared and defended in international fora, like the United Nations.

Depending on the relative importance of each of these factors, differing combinations of technologies, inspections, and protocols would provide varying levels of overall benefit for a given verification regime. For example, there may be some overall benefit to having inspectors on site even when the confidence in compliance related to that specific inspection is not significantly improved (as one might argue is the case for the use of CORRTEX during underground nuclear testing). The relative values of these objectives, therefore, should have a direct bearing on verification requirements, which in turn should help determine which verification research and development activities to pursue. The framework I described lends itself to accounting for such relative priorities.

In addition to assessing their relative importance, each factor on the benefit side of the equation must be weighted to account for the need or desire to achieve these benefits. Specifically, weights could be used as a means to address the risks of noncompliance, the need for enhanced stability, and the potential benefit to engaging the international community in a dispute. The appropriate weights for this purpose should be derived from separate but related policy analyses, the nature and scope of which I will defer to another time.

The cost side of the equation, while perhaps more straightforward and familiar, is no less difficult to estimate. Its factors include:

- Research and development costs associated with monitoring equipment and required support equipment (both hardware and software)

- Acquisition costs associated with the same

- Operations and maintenance costs

- Other implementation costs, including the expenses associated with infrastructure and analysis, as well as any other direct inspection costs

- Operational impacts on the forces and other entities subject to inspection

- Technological risks inherent in attempting to bring an inspection technique or system to fruition

- Counterintelligence risks associated with revealing information that is sensitive and not required for demonstrating compliance, and

- The risks of divulging proprietary information that could weaken a company's standing in the global marketplace. (This last item, incidentally, is a particular sticking point in the negotiations under the Chemical Weapons Convention.)

As I stated earlier, it will be difficult, if not impossible, to quantify the factors in this equation, except for perhaps some rough cost estimates. Nevertheless, I believe that the use of such a framework will aid in the choice of a verification regime, as well as in the research and development plan necessary to support it.

Given the current pace of developments throughout the world, this framework will need to be revisited from time to time to reassess the relevance of the verification regime and research and development program insights that it can provide. If, for example, tensions begin to ease between arms control participants, as they have between the United States and the former Soviet

Union, requirements for formal compliance verification may begin to wane while requirements for monitoring associated with confidence building remain strong. In such cases where the relative values of the benefits, or verification objectives, vary over time, the assessment process and the factors will remain much the same, but the results are likely to be different. This, in turn, will once again lead to different requirements for verification research and development.

Generally speaking, however, as relationships among nations with arms control agreements either in place or under negotiations improve, the total benefits that could accrue from a particular verification regime are likely to be reduced out of proportion to any reduction in costs and risks. This can be accounted for by changing the weighting factors in the equation that I mentioned earlier. Hence, the framework allows for addressing what is intuitively obvious: as relationships improve, strict or elaborate verification is less likely to be worth its costs.

ARTICULATING AND SATISFYING VERIFICATION R&D REQUIREMENTS

The framework I just described provides an opportunity to explicitly articulate and weigh verification objectives. It is these objectives, tempered by considerations of cost and risk, that should guide any verification technology research and development program. However, for the program to be both effective and efficient, it must be reasonably structured. To that end, I submit the following approach to satisfying verification research and development requirements. Once again, there is nothing terribly new about the distinct elements of this approach. However, in the interest of improving the coordination of resources to ensure that they are being applied against the proper objectives and in the areas of greatest potential payoff, I present this overall scheme for consideration.

The process should begin with an identification of treaty limits that are subject to monitoring and verification. In the case of pending negotiations, hypothetical limits should be addressed. These limits generally take the form of bans or restrictions on equipment and activities.

From these limits, monitoring requirements should be derived. These monitoring requirements must account for the nature of the limitations and the conditions under which the items or activities must be monitored. (Note: I'm making a distinction here between monitoring, which has to do with the collection of information, and verification, which involves making a judgement regarding compliance. In the latter case, political as well as technical information is factored into any decision.) Factors that affect monitoring requirements include:

- Whether the agreement calls for a ban or a limitation on quantities (i.e., does the mere existence of an item or the existence beyond some threshold constitute a violation?)

- Whether the agreement covers production, development and testing, use, or storage

- Whether the agreement limits transfers of materials or equipment to third parties

- The possible life cycle states of the limited items, and

- The access conditions that might be allowed for monitoring (e.g., how close will the inspector or the inspection equipment be to the inspected item?, will it be concealed in any manner, such as in a canister or in a building?)

The next step in the process is to identify observables associated with these monitoring requirements. The identification of observables includes, but is not limited to that which can be observed visually, like physical characteristics of limited items or troupe movements. It can also include phenomena associated with other forms of electromagnetic radiation, seismology, acoustics, gravity, chemistry, and biology.

Once discrete observables have been identified, these observables must be analyzed to determine their ability to satisfy monitoring and verification requirements. Questions that need to be addressed at this stage include:

- Is the observable unique, i.e., does it provide a signature of the item or activity to be inspected, or merely an indication of it?

- Is the observable reliable, that is, will it always be there at the time of inspection, and will it "look" the same each time?

- Can the observable be masked or spoofed?

While the value of an observable will depend on the outcome of answers to the above questions, it need not attain a perfect score in order to have some utility in meeting the monitoring and verification requirement(s). However, the limitations of its utility must be understood. For example, chemical signatures can degrade with time. Now, if the persistence profiles of these chemicals under various conditions are known, then it is possible to have some understanding of how long a particular signature might be detectable in a given inspection scenario. This is useful information for verification. The fact that a chemical degrades should not deter us from looking for it. Often it will be the case that multiple observables should be monitored to hedge against the weaknesses of any single one.

The next step in this process is to identify and analyze the potential means to exploit or measure useful signatures and observables. The means for exploitation could involve space-, aerial-, or terrestrially-based systems. They might involve passive, active, or interactive techniques. And, they may require varying levels of human involvement ranging from making the observation or measurement, perhaps with the aid of some device, to periodically tending a remote sensor, like a seismograph or a chemical sniffer, to merely analyzing data from remotely operated systems, like Landsat or SPOT.

At this point in the process, a technology survey is in order. The survey should encompass technologies that are already available commercially, as well as those in some state of research and development (and not necessarily geared toward verification applications). The appropriate level of research and development covered by the survey will depend on the degree of urgency for meeting the verification requirement. Regardless of the state of development, some amount of engineering and system integration will likely be necessary to bring the technology to a useable form for monitoring or inspections.

Prior to developing fieldable systems, however, the results of the survey need to be evaluated in order to ascertain in each case the relative utility of the exploitation system, the level of maturity of the concept, the remaining technical issues, the risks that these issues will not be favorably resolved, and the cost and schedule required in attempting to resolve them. Factors that play into the evaluation of exploitation systems include:

- How reliable would it be?, i.e., would it provide a correct answer each time it is used?
- Would accurate interpretation of the observation or measurement require access to baseline information?
- How spoof resistant would the system and the protocols for its operation be?
- How intrusive would it be?, i.e., what, if any, sensitive information would be revealed beyond that required for inspection?
- How would it impact operations at the inspection site?
- How time consuming and complicated would it be to set up, use, and break down the system?
- Will it operate in all realistic environments?
- How difficult would it be to deploy it to the inspection site?, and
- How often or how long could it be used once deployed?

Once this analysis is completed, then a development, test, and evaluation plan can be developed and implemented that would lead to prototypes, and eventually fieldable systems.

A couple of points deserve mention here, however. First, as is typical of most similar processes, there should be some iteration among the stages as activities proceed. This will allow decisionmakers to adjust resource allocations to accommodate any new or different verification requirements, any promising new ideas that might come along for meeting a particular requirement, and any development or cost expectations that, after further investigation, do not appear possible to meet.

Second, in cases where the verification requirements are based on hypothetical arms control agreements or provisions, it may not be necessary, or cost-effective, to take the process all the way to fieldable systems. It may be sufficient to know for negotiations purposes that a particular limitation can be monitored by one or more signatures, and that it is possible, given a requirement, to field systems for exploiting these signatures in a "reasonable" timeframe (where what's reasonable is defined by the context of the negotiations). Aside from the obvious risk of spending a lot of money on development and building a system that may never get used, it is possible that advances in technology over the course of the negotiations could lead to a better, and perhaps cheaper, system prior to an agreement's entry into force.

Admittedly, the direction and pace of any negotiations is often difficult, if not impossible, to predict. Nevertheless, some judgement in this area is necessary to preclude the situation of a warehouse filled with useless systems.

As I mentioned at the beginning of my talk, the corollary issue of not having enough lead time for verification technology research and development is perhaps an even larger problem. To address this issue, it is essential to have a research and development program at some level that is generally directed at verification applications without much concern over specifications until such time as the concept matures. These programs should be concerned more about addressing fundamental issues of whether a system could reliably detect a particular signature, and whether the information contained in that signature could be interpreted correctly and meaningfully. Some of the ongoing work in acoustics and gravity gradiometry falls into this category.

SUMMARY

In summary, it is not surprising due to the diverse nature of their disciplines, that verification policy objectives and technology solutions tend to be out of sync. Complicating the situation, is the fact that the people representing either segment of this community understandably tend to speak different languages and have limited appreciation for the problems and concerns of the other. Moreover, redressing this situation will likely become even more difficult over time given the nature and pace of world events with a direct bearing on arms control.

In my opinion, several things can be done to improve this situation. One is to adopt a more rigorous means, along the lines of the cost-benefit framework I described earlier, for a) deciding on appropriate verification regimes to address U.S. arms control objectives, and b) developing more cost-effective verification research and development plans to support them.

Two, given the growing emphasis on nonproliferation, the blurring distinctions between strategic and conventional arms, and the multi-use potential of some verification technologies, there needs to be better coordination among policy makers with responsibilities heretofore aligned with traditional treaty areas. Three, verification research and development programs should be structured to follow the process that I outlined earlier, proceeding as much as is practical from treaty limitations and monitoring requirements to technology surveys and assessments, before getting involved in expensive prototyping and manufacturing of fieldable systems. And fourth, there needs to be a verification technology research and development program at some level to explore the feasibility of new monitoring concepts that could provide policy makers with new arms control options to consider.

Practical Application of Commercial Satellite Imagery to Arms Control Monitoring

R. Fritzel, E. Reynolds
Pacific-Sierra Research

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PREFACE

This paper provides background on the possible application of commercial satellite imagery (CSI) to arms control monitoring, outlines imagery terms of reference, describes available CSI technologies and systems, and discusses key practical considerations in using CSI for arms control monitoring.

The present role of CSI in arms control monitoring is limited to that of a contributing source of information for accomplishment of selective requirements. But the growing capabilities of CSI systems, the attention it is receiving in other countries as a contributor to multilateral verification aims, and the increasing interest abroad in multilateral verification suggest that the United States and others should more closely consider the practical aspects of using CSI for arms control monitoring.

I. Introduction

A. Use of Commercial Satellite Imagery (CSI) for arms control monitoring

The United States and the former Soviet Union have been using earth satellites for over thirty years. Since the late 1970's, the use of national technical means (NTM) of verification has increasingly been accepted as a beneficial arms control monitoring and confidence-building measure. The United Nations defines NTM as including, "... observation satellites, aircraft-based systems, such as radars and cameras, as well as sea- and ground-based systems."[1] Public knowledge that satellite observation was and is useful for arms control monitoring emerged during the 1970s, and appears to have been linked to events surrounding the second U.S.-USSR Strategic Arms Limitation Treaty (SALT) Talks.

In recent years, increasing consideration has been given to exploring the uses of commercial earth observation satellites for both military applications and arms control treaty monitoring. The reasons for this are obvious. The multispectral imagery from Landsat (originally designated the "Earth Resources Technology Satellite" – ERTS) offered possibilities for broader uses. Also, aggressive promotion of the capabilities of the French SPOT *(Système Probatoire d'Observation de la Terre)* since launch of the first satellite in 1986 (the second was launched in 1990) has included military applications. Possible uses of Landsat and SPOT imagery for other than civil and commercial peacetime purposes have been discussed in unofficial literature, and a recent Department of Defense report makes clear that "military applications inherent in the remote sensing capabilities of multi-spectral imagery (MSI) have been developed and are being expanded.... MSI provided direct warfighting support during Operation Desert Storm." Examples cited of the uses of Landsat imagery in Desert Storm include mapping, detection of marine subsurface features down to 30 meters (depending on the clarity of the water), military operations planning, training and preparation for strike operations and "unique information on Iraq's order of battle."[2]

CSI systems have the advantages of being in place, active, and offering a range of capabilities that appear to be applicable to arms control monitoring. Being commercial, technology transfer limitations and classification issues can be avoided in most circumstances. Other advantages are that MSI expands the range of coverage for observables compared to imagery limited to the visual region of the spectrum, exploitation technology is available with new innovations being developed in private industry, MSI appears to be cost effective for certain applications, and

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1 *Verification in All Its Aspects*, UN Document A/45/372, 28 August 1990.

2 Appendix on "Performance of Selected Weapon Systems" to the *Final Report to Congress on Conduct of the Persian Gulf War*, Department of Defense, April 1992, pages T-230- 232.

expected improvements in CSI systems by the late 1990s are expected to increase their effectiveness in most applications.

A recent news story points out that a close relationship appears to exist between civil and military satellite imagery applications in France. France has a "... wide-ranging research effort to couple its growing military space ambition with its already well-established civilian space program.... In a series of presentations ... [French] government and industry officials identified key areas of research in which the distinction between a military and a civilian space application is all but lost." For example, "... research is directed at blending radar and optical images from a satellite to permit easier analysis by ground teams ... [According to a French observation specialist,] 'Combining a radar image with an optical image from a SPOT satellite would make the analysis of the data easier for ground operations.'"[3]

Multilateral, cooperative verification carried out among groups of countries appears to be the dominant trend for the future of arms control, in contrast to the past era of bilateral agreements between the United States and the former Soviet Union that were monitored and verified by the two parties. Indeed, some cooperative verification activities have already been studied or practiced. These include international use of imagery collected by U-2 aircraft to monitor cease-fire lines in the Golan heights and the Sinai peninsula; world-wide technical tests sponsored by the Group of Scientific Experts of the Conference on Disarmament of seismic data exchanges applicable to cooperative verification of a nuclear test ban; cooperative on-site monitoring of suspected use of chemical weapons carried out under UN auspices during the Iran-Iraq war; and extensive planning for cooperative verification of conventional forces in Europe prompted by the treaty on Conventional Armed Forces in Europe (CFE). Use of CSI for arms treaty monitoring appears to be a normal progression for multilateral verification.

Earth observation and environmental monitoring itself is a major priority in the 1990s for many countries. For example the Director General of the European Space Agency (ESA) stated that "Ensuring the protection of the environment in which we live is accepted as a matter of paramount importance, requiring attention at the highest political level on an international scale."[4] The thrust of R&D toward enhancement of remote sensing technologies can be expected to lead to improvements in resolution, imaging features such as stereoscopic viewing, and responsiveness of CSI that should also benefit arms control treaty monitoring applications. It is thus reasonable to expect that future applications of CSI for arms treaty monitoring will derive from progress in earth observation and environmental monitoring CSI systems.

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3 Peter B. deSelding, France Seeks Civil, Military Satellite Link, *Defense News*, April 13-19, 1992, pg. 36.

4 Robina Riccitiello, Budget Cuts Unlikely to Hit Earth Monitoring, *Space News*, April 27 - May 3, 1992

Effectively, several factors limit the number of nations capable of developing and employing reconnaissance satellites. U.S. satellites are multi-million dollar investments. Additionally, space infrastructure, which includes launch facilities, telemetry stations, and control centers, is technologically complex and expensive, as is data processing and exploitation. Financial pressures are affecting the space programs of the U.S. and other nations.

To date, most reports discussing uses of CSI for arms control monitoring have been negative, with the focus on what CSI cannot provide. There is a tendency to regard the limited spatial resolution of CSI imagery as blocking its effective utilization for arms control monitoring, frequently without discussion of its multispectral capabilities and potential contributions. For example, some analysts dismiss CSI because the best available resolution of 10 meters is insufficient for counting tanks and other treaty-limited items (TLI) under the CFE Treaty, or missiles under the INF Treaty. The potential for contributions of CSI in preparation of site diagrams, wide-area search, and other possible roles could be exploited to a greater extent. CSI can assist in the selection of targets for OSIs and possibly provide useful assistance during their actual performance. CSI does not have to replace other verification measures, such as on-site inspections (OSI), to contribute to arms control monitoring.

B. Open Skies Imagery

In March 1992, 24 countries signed the Open Skies (OS) Treaty. This agreement allows imagery sensor-equipped aircraft to periodically overfly the territories of the signatories. As publicly announced, OS aircraft will carry a suite of imagery equipment including panoramic, framing, and video cameras, an IR line scanning (imaging) system, and synthetic aperture radar (SAR)[5]. Resolution of the OS SAR will be 3 meters, with a sideways-looking swath width of 25 km. Some analysts have suggested using OS or a variation for specific arms control monitoring missions such as those mentioned in this paper for CSI[6]. A process of using CSI to cue OS flights to provide imagery that might then be used as contributing evidence for challenge OSIs might also be considered.

OS imagery, whenever available, can always be expected to be of superior spatial resolution to CSI. In contrast, the worldwide scope of CSI coverage substantially exceeds that of OS.

II. Terms of Reference

Resolution, also referred to as instantaneous field-of-view (IFOV), is the most common characteristic of an imagery sensor that is used to define the interpretability of its imagery and to compare one system with another. Spatial resolution is the minimum distance between two

5 Department of State Release, 24 March 1992.

6 Amy Smithson and Michael Krepon, *Strengthening the Chemical Weapons Convention Through Aerial Inspections*, Henry L. Stimson Center, Washington, DC, April 1991.

objects that permits them to be distinguished as separate objects[7]. Sensors are often described in terms of their pixel (picture element) size. Pixels can be likened to stones in a mosaic. The smaller the stones, the more detail that can be seen in the mosaic. Smaller pixel size corresponds to higher resolution, and the lower the number given for spatial resolution, the better the sensor's ability to differentiate among objects on the ground. For example, a sensor with 30 meters spatial resolution, such as the Landsat Thematic Mapper (TM), might be able to detect the presence of a large aircraft on the ground. Spatial resolution in the one meter range would be able to identify the aircraft as a B-52 bomber, possibly the type (B-52G or H, for example). CSI spatial resolution is at present in the 10-80 meter range.

There are several levels of utility for CSI:

- *detection* (of units, objects, or activities of military interest)
- *general identification* (determination of general target type)
- *precise identification* (discrimination within a target type)
- *description* (dimensions, configuration, components, equipment, etc.)
- *analysis* (changes, equipment characteristics, status-keeping, etc.)

Spatial resolution required for these tasks ranges from several meters for detection to fractions of a meter for analysis[8].

The term "spectral resolution" refers to the number and width of the spectral bands. For example, Landsat's seven narrow bands offer greater spectral resolution than SPOT's three wide bands. Hyperspectral imagery gets its name from the use of a large number of very narrow bands.

Resolution is affected by a number of variables. The altitude of the satellite is extremely important. Most observation satellites operate in 600-800 kilometer orbits. Imagery satellites in lower orbits can provide increased resolution but in higher orbits, increased satellite lifetimes are obtained. Atmospheric friction in lower orbits also forces satellites to carry more fuel for station-keeping, thus limiting their payload capacity. Other factors impacting on resolution include the viewing angle for those satellites with steerable sensors (generally, the more off-nadir the viewing angle, the poorer the resolution), satellite motion, atmospheric disturbances, the shape of the observable, and the brightness contrast between object and background.[9] Cloud coverage limits the effectiveness of optical and IR sensors. Radar is not affected by cloud cover, but may

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7 UN Document A/AC.206/14, 6 August 1981, pp.15-16, used in Bhupendra Jasani, "Sensor Capabilities," in Bhupendra Jasani and Toshimbi Sakata, eds., *Satellites for Arms Control and Crisis Monitoring* (Oxford: Oxford University Press), 1987, pp. 9-10. Book hereafter referred to as Jasani and Sakata.

8 Taken from table in "Nations Without Space Intelligence," Jeffrey T. Richardson, in Michael Krepon, Peter D. Zimmerman, Leonard S. Spector, and Mary Umberger, eds., *Commercial Observation Satellites and International Security*, (New York: St. Martin's Press), 1990, pp. 165-6. Hereafter referred to as Krepon et al.

9 NATO Industrial Advisory Group, Document SG 32/SMG/FDR, Final Draft report, March 1991, p.27. Hereafter referred to as NATO.

be sensitive to other atmospheric phenomena. Merging of digital data from different sensors and bands on the same satellite, and/or data from different sensors on different satellites, offers the possibility for improved resolution. Merging of SPOT panchromatic and Landsat multispectral imagery is fairly commonplace. A merge of Landsat TM data with SPOT panchromatic data gives imagery combining the spectral qualities of Landsat with resolution approaching SPOT's spatial resolution of 10 meters. The French are reportedly studying merging of SPOT panchromatic imagery and ALMAZ SAR data. Enhancements in interpretability available through merging of various combinations of digital electro-optical, MSI, and SAR imagery data are a key advantage of CSI.

Revisit time is another important consideration in comparing satellite systems. "Revisit" refers to the length of time before a satellite is in position to re-image the same area on the earth. There are two primary factors affecting revisit times for a given orbit: swath width and tilting capability. Generally, the wider the swath width, the shorter the revisit time, but as mentioned with poorer resolution off-nadir. SPOT and Almaz offer tilting capability. Either by the use of mirrors or by tilting the whole satellite, these systems can image areas on the earth's surface that are not directly below them and beyond their nominal swath width. This feature allows shorter revisit times, at the cost of lowered resolution at the edges of high-angle images. Tilting systems also enable analysts to obtain stereoscopic (three dimensional) images by pairing imagery of the same site taken from different angles.

III. Available CSI Technologies

A. Electro-Optical Cameras

Electro-optical cameras are similar to the video cameras familiar to most Americans. In these cameras, an optical system focuses reflected or emitted energy on special detectors, producing an electrical signal. This signal is either beamed directly to ground stations or recorded on tape for later transmission when the satellite is in range of the ground station. It is processed at the ground station and forwarded for evaluation. Current resolutions are between 10 and 30 meters for commercial systems.

B. Multi-spectral Imagery (MSI)

MSI uses several sensors operating in various spectral bands (Figures 1 and 2). MSI can be processed to allow the analyst to "see" more than the visible images available to the human eye. In addition to providing for addition of color to the image, MSI offers the capability to measure temperature differences and other geological and environmental factors by using one or more bands in the infra-red (IR) spectrum. For example, heat emanating from a facility declared to be closed (which may be an indication of covert production) could be detected with MSI.

C. Synthetic Aperture Radar (SAR)

Radar has distinct capabilities compared to optical cameras in that radar depends totally on reflected energy. Radar emits its own signals, and measures the time between transmission and the reception of the reflected signal to obtain an image. Radar gives a satellite, such as the Russian Almaz, all-weather capability and does not require a sun-synchronous orbit to allow 24-hour imaging[10]. Limiting factors are the power of the transmitter and the size of the antenna. The term SAR refers to a technique that takes advantage of the forward motion of the sensor to give a smaller antenna the effectiveness of a much larger antenna. SARs are employed on aircraft and satellites, and have resolutions in the 10-50 meter range for satellites.[11]

IV. Active CSI Systems

A. Landsat

Since the launch of Landsat 1 in 1972, four more satellites have been added to the Landsat constellation, of which two remain operational. NASA launched the identical Landsats 4 and 5 in 1982 and 1984, respectively, and turned them over to commercial operation by the Earth Observation Satellite (EOSAT) Corporation in 1985. Sensors include the multi-spectral scanner (MSS) and the TM. Landsats 1, 2, and 3 also carried the MSS, which has four spectral bands, 80 meters resolution, and a 185 kilometer swath width. The TM is a more advanced MSS, with six bands in the visible and short-wave IR spectra and 30 meters resolution, and a seventh band in the thermal IR with 120 meters resolution. The TM also has a 185 kilometer swath width[12] and a 16 day revisit time. Figure 1 specifies the spectral bands of the Landsat TM and typical uses for each band.

Landsat 6, originally scheduled to be launched in 1988, is currently slated for launch in early 1993. It will retain the Landsat 5's sensors and add a panchromatic (black and white) band of detectors with resolution of 15 meters. Landsat 7 is scheduled for launch by the Department of Defense around 1998, but its design has not yet been finalized.

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10 Frederick J. Doyle, "The Utility of Civil Remote-Sensing Satellites for Arms Control Monitoring" in Jasani and Sakata, p. 56.

11 Telephone conversation with Lou Weren, Almaz Corp, 30 April 1992.

12 Frederick J. Doyle, "The Utility of Civil Remote-Sensing Satellites for Arms Control Monitoring" in Jasani and Sakata, p. 53.

Band	Wavelength*	Spectrum	Typical Uses
Band 1	0.45 - 0.52μ	Visible Blue	Coastal water mapping Soil/vegetation differentiation Deciduous/coniferous differentiation
Band 2	0.52 - 0.60μ	Visible Green	Green reflectance by healthy vegetation
Band 3	0.63 - 0.69μ	Visible Red	Chlorophyll absorption for plant species differentiation
Band 4	0.76 - 0.90μ	Near IR	Biomass surveys Water body delineation
Band 5	1.55 - 1.75μ	Mid IR	Vegetation moisture measurement Snow/cloud differentiation
Band 6	10.4 - 12.5μ	Thermal IR	Plant heat stress management Other thermal mapping
Band 7	2.08 - 2.35μ	Mid IR	Hydrothermal mapping

Figure 1. Landsat spectral bands[13]

*microns

B. SPOT

SPOT 1 carries two linear array sensors that produce panchromatic images of 10 meters resolution, and another sensor with three bands each offering 20 meters resolution. The identical satellite SPOT 2 followed in January 1990. Deactivated at the end of 1990, SPOT 1 was reactivated in March 1992. SPOT 3 is already built and will follow when needed, probably in 1993. Figure 2 identifies the spectral bands of the SPOT system. The visible and IR bands offer 20 meter resolution, while the panchromatic band offers 10 meters resolution.

SPOT's advantages over Landsat are its improved spatial resolution and its ability to vary its sensor off-center through the use of a tilting mirror assembly. This latter capability shrinks revisit times to only four days and allows for stereoscopic (3-dimensional) imagery using images

[13] Table taken from U.S. Geological Survey/National Oceanic and Atmospheric Administration, *Landsat 4 Users Handbook*, p. 4-1. Hereafter referred to as Landsat Users Handbook.

of a target taken at different angles on different orbits. SPOT's disadvantage vis-a-vis Landsat is that it only has a three band MSI sensor, as opposed to Landsat's seven band sensor.

Wavelength*	Spectrum	Typical Uses
0.50 - 0.59μ	Visible Green	Green reflectance by healthy vegetation
0.61 - 0.68μ	Visible Red	Chlorophyll absorption for plant species differentiation
0.79 - 0.89μ	Near IR	Biomass surveys Water body delineation
0.51 - 0.73μ	Panchromatic	Black and white imagery

Figure 2. SPOT spectral bands

*microns

SPOT 4 will add an additional spectral band in the mid-IR range, improve on-board registration of 10-20 meter data, and increase design life to 5 years[14]. It is scheduled for launch in 1995[15]. SPOT 5 is still in the requirements definition phase, but it will probably feature improved resolution, down to 3-5 meters, and along-track stereo acquisition capability. Launch is tentatively slated for 2000. SPOT imagery is sold to all customers, although there was an interruption in this policy during the Persian Gulf War caused by the UN embargo on commerce with Iraq.

C. Almaz

Almaz 1 is the Russian commercial radar satellite, launched in 1991. Although intended to use two antennas, one failed and the SAR must function with only one. Nominal resolution is 10-15 meters, although additional processing, as yet unavailable to commercial customers, may improve this number significantly. Almaz is by far the largest of all commercial satellites, weighing 18.3 metric tons. The satellite can be rolled to achieve various angles of observation. Presently, Almaz Corporation, the U.S. commercial outlet for Almaz imagery, will sell images without restriction. Almaz 1-A was scheduled to be replaced by Almaz 1-B in 1992, but the breakup of the USSR and subsequent loss of funding has delayed that launch, as well as that of

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[14] Telephone conversation with Clark Nelson, Director of Communications, SPOT Image Corp., 30 April 1992.

[15] NATO, p.32.

the improved Almaz 2, previously slated for 1995-6. Almaz 2, although primarily an environmental research satellite, will have 3 bands of radar with 5 meters resolution, and will be at least as large as Almaz 1[16]. Prior to Almaz's launch, the Soviet firm Soyuzkarta marketed photographs in the 5-10 meters resolution range from a variety of remote-sensing satellites[17].

D. Other CSI Systems

1. ERS-1

ERS-1 was launched in 1991 by the European Space Agency (ESA). It carries a 30 meter resolution SAR with a 100 kilometer swath width. ERS-1 "... specializes in monitoring ocean temperatures, wind speed and ice levels,"[18] plus the height of the ocean waves. The SAR, due to limitations in its solar array capability, can only collect data in 14-minute windows. ERS-1 carries several other low resolution sensors for environmental research, such as determining water vapor levels in the atmosphere. ERS data is processed and archived in the U.K. and Italy. Germany also has a processing center.

According to a recent article, "The ERS-1 ocean data and polar ice information is used by the shipping industry and off-shore oil exploration companies as well as scientists and environmental analysts.... The satellite's successor, ERS-2, scheduled for launch in 1994, will be similar to ERS-1 but also will have equipment to monitor global ozone levels. The ERS-2 program is expected to cost less than $500 million, including the launch. ESA paid more than $900 million for the ERS-1 program, which included the costly development of the satellite and the construction of many ground control stations."[19]

2. MOS-1

Japan's Marine Observation Satellite (MOS-1) is a remote-sensing satellite launched in 1987. It has 50 meter resolution on its four channel sensor and a 14 day revisit time.

3. JERS-1

The Japan Earth Resources Satellite (JERS-1) was launched in February 1992. It carries an 18 meter resolution SAR with a 35° off-nadir capability and a swath width of 75 kilometers. Initial problems with antenna deployment have apparently been solved. Optical sensors will scan two visible (green and red) bands, one near IR band, four shortwave IR bands, and one stereoscopic IR band, all with 24 meters resolution. The repeat cycle will be 44 days. Japan has promised to make JERS-1 data available without restriction.

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16 Telephone conversation with Lou Weren, Almaz Corp, 30 April 1992.

17 Leonard S. Spector, "The Not-So-Open Skies" in Krepon et al.

18 Robina Riccitiello, Scientists Express Dismay Over Slow ERS-1 Data Flow, *Space News*, May 11-17, 1992, pg. 24.

19 *Space News*, pgs. 9, 12, Apr 27- May 3, 1992

4. Forthcoming systems

a. RADARSAT

RADARSAT is a Canadian venture scheduled for launch in 1994-5 by the Canadian Space Agency. The primary sensor will be a SAR with five variable beam modes, providing various swath widths (45, 75, 100, 150, and 300 or 500 kilometers), resolutions (10, 28, and 100 meters), and incidence angles. Revisit time will be 24 days.

b. POEM-1

The keystone of ESA's future Earth observation program is the $1 billion Polar Orbit Earth Observation Mission (POEM-1), contained on a massive polar platform satellite that will monitor ozone depletion, ocean temperatures, climate change and other phenomena. The first satellite is scheduled for launch in 1998, the second in 1998-9. "'The payload of the polar platform will be more than twice as heavy as ERS-1. Its instruments have a far bigger scope and encompass more areas of earth sciences,' said ESA spokesman Claus Havfast."[20] Final structure and identity of the individual elements have yet to be determined, although ESA intends to include a SAR in the payload. (POEM-1 was formerly known as the European Polar Orbiting Platform – EPOP).

V. Practical Considerations

The range of capabilities mentioned in the previous section have been found useful by a wide variety of customers. Practical considerations to determine the extent to which arms control monitoring tasks are suited for CSI capabilities include identification of observables, determination of collection requirements, estimation of costs, and evaluation of the implications of relying on commercial sources for what is in essence national security related information.

A. Identification of observables

The limited spatial resolution of current generation CSI restricts its use for many aspects of arms control monitoring. Current CSI images do not offer sufficient resolution to identify and prove violations of a treaty even in cases where TLIs may be extremely large, such as with the Krasnoyarsk large phased-array radar. However, certain objects of interest may be observable using CSI. Determination of which observables are detectable by CSI for arms control monitoring is a key step in the evaluation process.

According to a draft NATO study, general requirements for arms control monitoring include:

- Sites (both declared and undeclared)
- Infrastructure
- Movements (such as at checkpoints, staging areas, etc.)
- TLI parking areas

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20 *Space News*, pgs. 9, 12, Apr 27- May 3, 1992

- Detection, recognition, and possible identification of TLI
- Cueing on-site inspection.[21]

Although about 5 meters may be the minimum resolution required to completely fulfill each of these missions, there are observables in each category of requirements that can be detected using the current generation of CSI. Examples of observables include buildings, large equipment items, parking lots, storage areas, roads, railroads, security and other obstacles, and waste settling ponds. Other examples are in Table 1.

Sites may be monitored by observing the layout of buildings and other structures. CSI images may be used to develop site diagrams that can be compared with those provided by the inspected party. Construction of roads, fences, and other infrastructure changes should also be apparent with CSI. Detection of a security perimeter around a previously unguarded facility may be used to prompt queries about the purpose of the site. CSI's capability to image broad areas might also allow for detection of unannounced or previously uninspected sites that may require closer examination. According to NATO, "Resolution of this scale [SPOT's 10 meters] can reveal significant information on the status, layout, and order of battle of military sites, and can identify details such as aircraft parking aprons, hardened shelters, POL facilities, barracks, and so on. Changes in infrastructural features ... can also be observed over time."[22]

Monitoring of movement is more problematic with CSI. Relatively long revisit times must be taken into account in planning surveillance of movements associated with a given facility and unit. However, if weather or road conditions prevent rapid movement, a unit may be detected at different locations. Also, the presence or absence of a given unit at a parking area may be detectable, if the unit has observable TLIs or a sufficient number such that they are detectable as a group. For example, observation that a previously occupied tank park is now empty could cue analysts to search for the unit elsewhere, and prompt the government to request clarification of the unit's whereabouts.

B. Determination of collection requirements

For each arms control treaty, there are a number of objects of verification (OOV), of which TLIs are but one type. OOV may be military installations, equipment, or factories. They may be small or large, fixed or mobile. After the list of OOV is compiled, a nation or group of nations must determine the most efficient way of monitoring these OOV. There are several options, of which CSI is but one. Others include OSI, covert operations, and open source intelligence gathering. The monitoring nations must evaluate their resources, both economic and technical, and determine which methods are the most efficient for which OOV. The technical evaluation

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[21] NATO, p. 5.
[22] NATO, p. 17.

should include signature analysis – whether there are any observables detectable through remote sensing that can indicate the status of OOV. This is a process which works in two directions. First, CSI capabilities are evaluated to determine what can be seen. Next, OOV are examined to determine whether what can be seen by CSI is usable for arms control monitoring. When considering CSI, the characteristics of areas or facilities associated with TLIs that a CSI system can detect do not necessarily need to include features that can be specifically related to treaty limitations. The principle of observable surrogates of the TLI can be applied to the imagery exploitation. A surrogate observable (such as a canister for a missile) can provide, in properly defined circumstances, essentially the same information as observation of the actual TLI. Also, CSI area searches can provide status keeping and indications of change in status that would be clarified by OS flights or OSI.

After the various OOVs are matched to their collection methods (and multiple methods may be chosen for each object of verification), nations lacking NTM capability must determine if CSI is a useful addition to the group of available collection methods. If so, the necessary technical infrastructure for imagery analysis must be obtained, and analysts trained. As CSI infrastructure is very expensive, the formation of an international satellite monitoring organization could be a solution. Such an agency would pool resources of several nations for the purpose of monitoring arms control and other agreements, with a centralized data interpretation center. This would have the advantage of lowered costs, but without the flexibility of independent operation. Establishing a regional satellite monitoring agency under NATO auspices has been discussed.

Table 1 lists general types of areas or facilities associated with TLI in conjunction with the CFE, INF, START, and CWC arms control treaties and typical or exemplar status changes that may be interpretable in CSI. Being multilateral agreements dealing with conventional forces and their supporting logistical infrastructure, CFE and CWC will account for large numbers of areas and facilities that will require aperiodic monitoring over extended time frames. Thus, any cost-effective system for exploiting CSI imagery coverage (such as provided by Landsat) that can be shared with other nations could play a useful role and contribute to the solution of future arms control verification problems.

Type area/facility	Potential status changes
CFE	
Ground force unit garrisons (battalion and above)	Reoccupied with same echelon unit, reduced activity, unoccupied. Readiness category status changes.
Ground force unit training areas	No change, increased use, increased size, reduced use, reduced size, abandoned
Ground force equipment storage-forward	Reoccupied with same echelon unit, reduced or increased amount of storage, secured pending movement to dismantling area
Ground force equipment storage-rear	Increased TLI stored pending dismantling
Supply, ammunition, and POL storage-forward	Reduced or increased amount of storage
INF, START	
Missile operating bases	Reoccupied with different system, converted, unoccupied, dismantled
Missile and launcher storage facilities	Increased TLI stored pending dismantling
Missile test and training facilities	Active with different system, inactive
Missile and component production facilities	Changed items produced and output, inactive, dismantled
CWC	
Chemical agent production facility	Secured pending dismantling
CW loading/filling facility	Converted, unoccupied, dismantled
Storage facility for bulk chemical agent	Secured pending removal of bulk agent
Storage facility for chemical munitions	Portions secured pending removal of chemical munitions and related equipment

Table 1. Candidate areas and facilities for CSI arms control monitoring.

A country or group of countries planning to use CSI for arms control monitoring can consider the use of both existing and newly-acquired imagery. The simplest option is to use existing imagery. This has the advantage of being more readily available and already processed, allowing use soon after the request for purchase. Imagery may be delivered within days after order. However, certain areas of the earth's surface may have been ignored for months or even years at a time, leaving the purchaser with the possibility that no usable imagery may be available. Other disadvantages include a potential lack of timeliness, as the image may be months or even years old.

The second option for CSI use is to procure new images. This has the advantage of being as up-to-date as possible, and tailored for the intended purpose. However, requests for specific imagery targeting may have to wait until the needs of other customers have been filled, and then must be processed after imaging. This processing is only limited, and most users will perform additional processing after receipt of the data. Even with no scheduling problems, the time between request and arrival of imagery is usually several weeks. The desire for accuracy must be balanced with cost and the requirement for timelines.

C. Estimation of costs

SPOT and Landsat image frames cost, after processing, between $3000 and $6000 each. Quarter frames are correspondingly less expensive. Almaz images are about $2400 each. In addition to the cost of the images themselves, users must also train analysts to interpret them once they are obtained. Training is expensive, and image interpreting is a perishable skill which requires continuity. It is not feasible for a country to simply order a few images a year and expect the analyst to be able to maximize the information available. Hardware and software costs to support image interpretation would be, at a minimum, several tens of thousands of dollars and likely much more. Once a nation decides to use CSI, for whatever the mission, the infrastructure costs will be ongoing.

An essential element in determining the cost of CSI use is the collateral information gained with each image. The nature of the data needed makes it a technical impossibility to limit the information gained to treaty monitoring. A frame of Landsat imagery contains much information beyond that of an individual target of interest. For example, a missile field might only be twenty kilometers on a side, covering a fraction of the area of the imagery frame. The rest of the image comes with the purchase price, and it would not be cost-effective to ignore this data in hand. Detection of other items of interest can be expected while analysts are scanning see what else can be found in the imagery. Also, due to the large area of each image, CSI imagery exploitation may go into economic, agricultural, resource, or other areas of monitoring. The analyst may not be able to find what is primarily being sought, but there is likely to be other information in the image of value to other organizations or agencies within the government besides the arms control community.

To purchase a quarter frame of SPOT imagery covering an area of approximately 200 square miles and only interpret the data on a single location would be akin to buying a map of the

District of Columbia but only looking at the White House. In practical terms, the specific size of the commercial satellite image that must be purchased dictates that cost-effective use of the data involve exploiting anything in the image of current or future value. In short, the CSI data, once purchased, will need to be used to the maximum extent.

This same issue is inherent in exploitation of Open Skies imagery. The treaty provides ground rules for carrying out imaging flights and arrangements are being negotiated for archiving the resultant imagery. The intention for having the imaging flights take place is confidence-building, but the data, once archived, will not necessarily be used only for confidence-building purposes.

D. Reliance on commercial sources for national security information.

During the recent Persian Gulf war, SPOT Image Corporation and Almaz Corporation in the United States refused to sell images of the battle zone to Iraq or any nation which might possibly pass the images to Iraq. While this was justified by the trade embargo imposed on Iraq by the United Nations, the issue remains that SPOT Image and EOSAT are strictly regulated by their respective governments, and Almaz Corporation by the laws of the host country, in this case the United States. While all three countries, as well as Japan with its JERS-1, have promised to make CSI available on the open market, these images can be embargoed. The availability of CSI is ultimately dependent on the goodwill of the governments operating the observation satellites.. A country or group of countries probably will wish to limit its degree of dependence on commercial sources for national security information. For this reason, CSI for many countries will remain an adjunct to other methods of information gathering for arms control monitoring. The incentive for individual nations (e.g., India) to launch their own observation satellites is apparent.

VI. Summary

CSI shows promise for making significant contributions to the monitoring of arms control treaties and agreements. Unfortunately, practical analysis of the utility of this advanced technology has been insufficient.

President Carter's official public acknowledgment in 1978 of U.S. photo reconnaissance capabilities resulted, among other things, in a certain degree of public discourse on the ways and means of arms control treaty monitoring and verification. The United States publicized that the Soviet Union possessed satellite imagery capabilities. In instances of bilateral arms control negotiations, the perception of verification capabilities fit with the general concept of balance that was so important to the political-military climate of U.S.-Soviet arms talks. As pointed out in a UN study, "The important role of NTM is acknowledged in arms limitation and disarmament agreements that include obligations not to interfere with these devices."[23]

Today, multilateral verification is becoming prominent. Canada, Japan, China, and India have launched or are planning observation satellites that all appear to have some military support capabilities. France's planned HELIOS, a military satellite on a civilian SPOT "bus," may offer much higher spatial resolution than SPOT. However, not every country or group of countries has the technical or economic resources to acquire and launch its own reconnaissance satellites and made cost effective use the imagery data that can be obtained. To provide satellite imagery to countries without indigenous observation satellites, some have advocated creation of an International Satellite Monitoring Agency for the United Nations, or a Regional Satellite Monitoring Agency (RSMA) in Europe. Under the multilateral concept, several nations would jointly develop, produce, and launch a series of satellites to monitor arms control agreements. CSI data would be processed by the international or regional monitoring agency and made available to nations contributing to support of the agency.

Even though the RSMA idea was first presented by France in 1978 and repeated in 1987 as an Agency for Treatment of Space Images, no actual results have been achieved.[24] A significant obstacle is the cost involved in developing the satellite. Cost effectiveness in an environment of reduced government budgets is a key consideration. Italy and Spain are assisting France in construction of the HELIOS satellite, and France has offered to contribute data to an RSMA if established by the Western European Union (WEU). Canada has been advancing a similar RSMA concept, known as PAXSAT, and fears that a European organization would undermine its idea[25]. Significant political and economic hurdles remain ahead for any of the CSI monitoring agency plans. A major issue is the agreed interpretation of data. Who decides, in a consortium, on the final interpretation of data?

Scientists from Canada, Czechoslovakia, France, Great Britain, Netherlands, the United States, and the former Soviet Union are participating in the Ruhr University Verification Project. In describing the context of their research, the Ruhr University researchers point out that "Cooperative methods of verification may include:

- cooperative satellite monitoring,
- aircraft overflights,
- human inspections,
- tagging,
- near-distance sensors."

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23 ibid.

24 "France Wants Military Space Talks," *Military Space*, December 19, 1988.

25 "HELIOS Data Access 'Would Be Limited,'" *Jane's Defense Weekly*, 20 April 1991, p. 621.

Further, "If designed properly, cooperative methods can avoid destabilization and contribute to confidence-building."[26]

Researchers at Ruhr University in Bochum, Germany make interesting distinctions between NTM and cooperative verification. In describing the context for their work, they argue that NTM "will continue to exist [but that NTM]

- Are not equally available to all countries,
- Properties and the information gained are secret, and
- Results can directly be used for targeting and attack planning."

These distinctions may be adequate at present but cannot be expected to survive the improvements in CSI technology expected by the mid- to late 1990s. It seems unavoidable that CSI from even the existing systems, once collected and archived, will be used to contribute to broader military and national security requirements than arms control monitoring.

Benchmarking is needed to determine what is detectable and identifiable, using known installations and equipment. Perimeters of sites or facilities of interest could be determined using CSI, and then tested for ground truth. Images of different installations and TLI should be examined to determine signatures. Further research along these lines can determine the specific utility of CSI for arms control monitoring.

Countries unable or unwilling to pay the costs associated with participation in an international or regional satellite monitoring agency but requiring monitoring information may consider using CSI available from the currently active satellites. Data from the United States' Landsat and France's SPOT is available commercially and may be cost effective for certain requirements of limited duration or intensity.

The resolution of currently available CSI is too poor for the actual counting and identification of smaller TLIs. However, counting and identification of TLIs is only one factor in arms control monitoring and verification. Some objects or events that are important to a country's arms control monitoring needs can be detectable and identifiable by Landsat and SPOT. For example, a nation may be able to detect and identify construction of weapons production facilities, monitor military maneuvers, monitor the operational status of facilities, and, in some cases, determine the size of a prospective opponent's armed forces. The limited capabilities of present-day CSI systems appear to be suitable for these tasks, and planned improvements to the capabilities of Landsat, SPOT, and upcoming systems will add to the list of tasks that CSI can perform.

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[26] J. Altmann, *et. al.* Research Project: New Technical Means for Cooperative Verification in Europe, Ruhr University Bochum, Federal Republic of Germany, 1992.

Open Skies Treaty: Imaging Radar Technology Issues

M. Sandoval
Sandia National Laboratory

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I. Introduction

The Open Skies Treaty is a confidence-building regime that allows the manned aerial overflight of participating nations with multi-sensor suites in order to monitor any militarily significant activity. This treaty was first proposed by President Eisenhower, but due to the poor political climate at the time was never implemented. During a May 1989 speech at Texas A&M University President Bush proposed a multilateral Open Skies Treaty which would permit NATO aircraft carrying various types of sensors to overfly Warsaw Pact countries and vice versa. The purpose of the proposed agreement was to use aerial surveillance to promote openness and to further reduce tensions in Europe.

The US effort to meet treaty requirements concerning implementation of the hardware technology and conform to international rules on exportable technology has taken almost two years. Since the initial meetings at NATO headquarters in Brussels, world events have changed the initial implementation scenario. Events such as the unification of Germany and the re-organization of the former Soviet Union have increased the European community's interest in such a monitoring regime to further enhance peace and confidence in the international community. In fact, opposition to such an agreement has decreased to the point that a treaty was signed by heads of state in March 1992.

This paper will present an overview of the technical analysis, discussions, and negotiations associated with the inclusion of a day/night and all-weather imaging radar sensor capability in the Open Skies regime. Discussion on agreed-upon treaty requirements and the unresolved technical issues to be discussed in future Open Skies Consultative Commission (OSCC) meetings will also be presented. Participation by the author in the discussions was sponsored by the Department of Energy's Office of Arms Control and Nonproliferation.

II. Sensor Technology Levels

In the initial presentations of the requirements for the Open Skies Treaty it was agreed that the sensor technology to be used in the regime would be available to all participants of the treaty. However, the requirement to share the Open Skies technical equipment and data with all nations makes the implementation of the regime using state-of-the-art hardware a difficult requirement. The sharing of such sensors and aircraft equipment would have to be reviewed by the export-control authorities of each participating country in order to insure that no militarily significant technology would be released without proper approvals. This particular caution on release of significant or sensitive technology has led to a restriction on the level of technology to be used in sensor suites for the Open Skies regime. In addition, all participating countries must be able to acquire comparable levels of technology for the implementation of the sensors and aircraft for the regime.

Signatories to the Open Skies Treaty have suggested various sensor suite configurations. The first list was very extensive and was considered by many nations to be too costly and difficult to implement. After further review by participants of the regime the list of sensors was reduced to the four categories below:

(A) optical panoramic and framing cameras;

(B) video cameras with real-time displays;

(C) infra-red line-scanning devices; and

(D) sideways-looking synthetic aperture radar.

Export control considerations for imaging radar sensors such as Synthetic Aperture Radar (SAR) dictated an achievable resolution of approximately three meters in the slant plane. The SAR sensor is the only day/night and all-weather imaging capability that is being allowed for the Open Skies Treaty at the present time. It was felt by all participants of the regime that this type of sensor was essential for imaging territories in Europe that have a large number of cloud-covered days and would be crucial for flight crew safety, since it would enable them to fly above bad weather and avoid low-altitude data collection. In addition, night-time data collection could be accomplished if necessary.

Although the SAR is limited in performance by the technology level that is currently accepted by the participating nations, this level will, in the future, be reviewed for improvements. In the meantime, other performance limitations have been placed on the SAR in order to insure that the Open Skies missions can be achieved without controversy. For example, only sideways-looking modes will be allowed for the data acquisition with imaging radars. That is, either left-side or right-side patches of ground may be imaged from the aircraft, but not simultaneously. In order to insure wide area coverage with SAR and to insure that the participating nations have the technology level to achieve coverage with the agreed resolution, an upper limit of 25 km has been set on the swath width of the imaged area on the ground. To insure that the swath width is not too narrow for wide area search purposes, an acceptable lower limit on swath width extent will be discussed at the OSCC at a future date.

Technology level limitations have also influenced the hardware to be used for the data recording from the SAR sensor. The raw or unprocessed data from the SAR is called initial-phase data and, once the airborne mission is completed, requires processing on the ground in order to form an image. The treaty participants have agreed to record the initial-phase data on magnetic media without specifying the type (i.e., analog tape magnetic media, digital tape magnetic media, or other). Each signatory to the Treaty will make recommendations at the OSCC as to a preferred recording magnetic media and will also recommend the formats desired for data sharing. The Treaty also allows a country to request formed images instead of the unprocessed initial phase data. Data processing procedures have not yet been decided and the sharing of technology to process raw data are also not resolved. The final decisions on these unresolved issues will be discussed at the OSCC sometime this year and may require demonstration of the technology in order to determine the best option for all participants of the regime. Analysis in support of these issues is currently being formulated by all interested participants.

III. SAR Performance Metrics

The assurance of the performance of the sensor suite requires that validation methodologies and procedures be approved and accepted by all participants to the Treaty. Basic definitions of the performance metrics for the sensor suite continue to be major issues for OSCC negotiations. After much negotiation in November 1991 it was finally decided by all participants that, for the purpose of the Treaty, the definition of sensor ground resolution to be applied to all imaging sensors for Open Skies would be:

> The term "ground resolution" means the minimum distance on the ground between two closely located objects distinguishable as separate objects.

This lengthy negotiation of a basic definition foreshadowed the more complex technical discussions over sensor performance validation methodologies and procedures. In order to insure good quality data products from data acquisition flights, it was proposed that validation criteria be included in the Treaty and that techniques to verify these metrics be established.

In the case of the SAR, it was proposed that measurements of resolution, dynamic range, and sensitivity be made and compared with standards that have been agreed upon by all participants and stated in a future annex to the Treaty. There would also be a need for agreement on a standard sensor calibration methodology and procedure that would be implemented prior to operational data acquisition activity.

The 3-meter resolution requirement is stated in two ways in the current Treaty text and will need to be addressed during the next OSCC session. The problems with the current requirement statement is that one specifies 3 meters as the ground plane resolution and in another part of the Treaty it is stated as 3 meters in the slant plane. The resolution in the ground plane is a geometric function of the look angle or depression angle of the SAR and varies for different angles. The easier metric to verify would be the one stated as a measure of the slant plane resolution, which makes it independent of the depression angle. With a slant-plane specification there will be no need to specify a particular depression angle for the validation data acquisition flight tests.

Two current methodologies have been stated in the text for validation of the 3-meter resolution standard: impulse-response (IPR) methodology and object-separation methodology. Since additional validation equipment will be required if there is need to support two procedures, there will be a discussion in the OSCC to try and settle on just one method to verify resolution.

Impulse response (IPR) methodology is a measure of the width of the magnitude intensity of the SAR image of a trihedral corner reflector made of radar-reflecting materials on the ground, measured at the half-power points below peak intensity. The physical dimensions of the corner reflector should be smaller than the resolution cell size of the imaging radar. The electromagnetic size should be large enough to give a return signal well above the background return noise, but small enough to prevent saturation of the radar receiver. The electromagnetic size is a function of not only the physical dimensions of the corner reflector, but is also related to the frequency of the electromagnetic energy being transmitted and received by the imaging radar. Analysis has shown that an array of five to nine trihedral corner reflectors spaced about 30-meters apart on the ground would be required to assure the acquisition of at least a few good impulse responses in an image of the array. This spacing and number of corner reflectors is required due to the sampling nature of imaging radars, where there is not an easy way of assuring that the trihedral corner reflector will always be located exactly in the middle of the 3-meter resolution cell each time data is acquired.

Object separation methodology has also been proposed as a way to validate the resolution of the SAR. The proposed procedure is based on the imaging of pairs of corner reflectors in a large array located on the ground. The array would be composed of tens of pairs of corner reflectors in order to have a statistically significant sampling of object pairs in the image of the array. Each pair of corner reflectors would be separated by the stated resolution of the system. After image formation of the initial-phase data the image of the array is analyzed. For a successful validation to be declared, at least half the of the pairs of objects that have been imaged should be interpreted as being two separate objects in the image. The array would be positioned in such a way that the pairs do not electromagnetically interfere with each other and can be imaged as separate pairs of objects. The physical and electromagnetic sizes of the corner reflectors would be chosen using the same criterion defined for the IPR methodology. The exact separation between the pairs of corner reflectors in the object separation methodology will be discussed at the next session of the OSCC when imaging radar issues are revisited. An analysis will be presented at the OSCC to show how the two methodologies are related by adjusting the distances between the pairs of corner reflectors in the object separation methodology array to conform with the IPR array results to validate 3-meter resolution in the slant plane for the imaging radar. The object separation methodology requires a much larger array of corner reflectors than the IPR methodology array and thus impacts costs and logistics for deployment in the field. Further discussions on resolution methodologies have been delayed for presentation at the OSCC and a demonstration may be required to resolve this issue within the international community.

Also to be revisited will be the metrics proposed in earlier Open Skies negotiations that would define methodologies for validating system dynamic range and sensitivity. Dynamic range is the specification of an imaging radar system's ability to resolve small radar cross section objects and large radar cross section objects in the same image. The dynamic range requirement is crucial to insure that the imaging radar can image over a significant variation of target intensities and backgrounds and allow low intensity and high intensity objects to show up in the same image. Sensitivity of an imaging radar system is a metric that sets a limit on its ability to resolve the difference between objects that are of different radar cross section by a small amount in the same image. The exact parameters for specifying these two SAR performance metrics and the validation methodologies will be resolved in future OSCC discussions.

IV. Operational Deployment

The exact time frame for deployment of the SAR equipment for the Open Skies operational aircraft will depend on the resolution of political and technical issues and on the funding levels available. Assuming all relevant issues are resolved in the OSCC, a SAR system could be fielded in two years or less after funding has been allocated for the equipment. The SAR is more difficult to install in an aircraft than other sensors since it requires a radar energy transparent window (i.e., a radome) the size of the antenna system and it also requires an interface to either a dedicated inertial navigation system (INS) or to the aircraft's INS. The SAR for the regime must not only meet export restrictions, but the equipment must also have good performance specifications for reliability of operation, must be easy to operate, and must be maintainable in the field. The SAR technical operating parameters will have to declared, although not necessarily verified, since such information may be required to minimize potential problems of electromagnetic interference or to aid the image interpretation of the data. Examples of these types of parameters include operating frequency, electromagnetic polarization, pulse repetition frequency, and transmitter output power. Another operational deployment consideration will be the annotation of the acquired data sets. This is necessary to determine, after the fact, where data was acquired and for the purposes of storage and retrieval from archives. The Treaty has some preliminary annotation requirements specified for the SAR, but the exact annotation interval requirements will be decided in the OSCC.

In support of the airborne SAR equipment will be a data processing capability that is required to perform image formation of the initial-phase data. The exact configuration and composition of such a facility will depend on the form of the raw data to be processed. In the event that the raw data to be processed is on digital magnetic media a computer will be required to do the image processing. If this technology is to be shared than it must not have any export restrictions and the image formation software or algorithms must also be sharable. The details of the post-processing of SAR initial-phase data to form sharable product will be discussed at the OSCC.

V. Conclusions

With the increasing interest by the European Community (EC) in an effective confidence and security building strategy, treaties like Open Skies offer an opportunity for cooperative exchange in an international forum. The multilateral participation with the ground rules for shared technical equipment and data among the participants has allowed a wide range of participation in the negotiations. Utility of the Open Skies regime has been a subject for debate and may indeed prove not to be cost-effective, but the fact that there is international participation in a regime once considered too intrusive is a sign that openness by formally restricted states is finally being achieved. The Open Skies technology that is currently being allowed should be viewed as only predecessor aerial inspection technology. Improvements of the technology level for future regimes with different requirements will have to be negotiated if aerial inspection proves to be an adequate confidence and security building measure. The learning curve will be slow due to the difference in technology levels of the participating states, but the cooperative nature of the Open Skies regime allows for the pooling of ideas and equipment to accomplish the basic requirements of the Treaty. The equal sharing of the data products from the regime in an unclassified open environment should lessen suspicion and should aid in settlement of international disagreements.

Acoustic Resonance Spectroscopy in Arms Control Monitoring

K. Apt, D. Sinha, P. Lewis
Los Alamos National Laboratory

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ACOUSTIC RESONANCE SPECTROSCOPY IN ARMS CONTROL MONITORING

by

Kenneth E. Apt
Arms Reduction Verification

Dipen N. Sinha
Electronic Material and Device Research Group

and

Paul S. Lewis
Sensor Systems and Robotics Group

Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, NM 87545

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ABSTRACT

Acoustic Resonance Spectroscopy (ARS) is an acoustic-based, nondestructive evaluation technique that can detect anomalies in populations of similar items. ARS is evaluated for its possible application in arms control monitoring, particularly in relation to chemical weapons arms control agreements. Results of ARS measurements on actual chemical weapon munitions are given. ARS measures the vibrations of an entire object and can determine fill material of sealed chemical munitions under certain conditions but cannot image the interior of the item. The use of ARS in an analytical hierarchy is discussed. A program for evaluating ARS in strategic missile monitoring is described.

I. THE ARMS CONTROL CONTEXT

One of the central issues in arms control monitoring deals with confirming the authenticity of items or material covered by a treaty. In agreements such as the 1987 Intermediate-Range Nuclear Forces (INF) Treaty and the 1991 Strategic Arms Reduction Treaty (START), specific items must be authenticated to ensure that they are not prohibited by their respective agreements. The 1968 Nuclear Nonproliferation Treaty (NPT), however, accounts for special nuclear material and not items *per se*. The Chemical Weapons Convention (CWC) being negotiated at the ongoing Conference on Disarmament in Geneva combines aspects of both an item-based arms control regime and a material-based regime. In their own fashion, the verification regimes for each of these agreements must authenticate declared items or material.

Once a treaty-limited item (TLI) has been determined to be authentic, i.e., as declared, a related objective is to ensure that it remains so. In other words, the regime must ensure that an item is not altered in such a way as to violate the terms of the treaty. Following initial inspections, two approaches can be employed to ensure that an item remains technically allowed under a treaty: (a) periodic reinspection of the item to ensure its authenticity and (b) containment and surveillance of the item to detect possible tampering with or substitution of the item. These two approaches are not mutually exclusive, and an effective regime might employ both.

While a primary objective of arms control monitoring regimes is to confirm the authenticity of items or material, an ancillary objective must be to minimize the intrusiveness of the inspection and monitoring activities. Monitoring techniques combining both high confidence in verification and minimal intrusiveness are few. The method described here, Acoustic Resonance Spectroscopy (ARS), is one technique that can be used to balance the trade-offs between these conflicting objectives when authenticating items.

II. ACOUSTIC RESONANCE SPECTROSCOPY

Use of ultrasound in nondestructive evaluation (NDE) of materials dates back many decades.[1] Most commonly, ultrasonic NDE relies on the pulse-echo technique, which is particularly useful in studying plates and composite materials. In the 1960s, the Army Research Laboratory introduced a modification to pulse echo, which involved Fourier analysis of the echo signal to obtain information related to the configuration of voids and microstructure (e.g., grain size) of a material. This modified technique, known as ultrasonic spectroscopy, is not particularly useful for studying overall characteristics of objects because it conveys only localized information in the direction of the propagated ultrasonic pulse.

ARS[2] is a technique that overcomes many of the limitations of earlier acoustic NDE methods. By extending the frequency band to include frequencies below ultrasonic, ARS can measure larger-scale characteristics of an object. Further, by employing a swept-frequency excitation in lieu of a pulse, ARS can measure the resonance spectrum of an object with higher precision. ARS is under development and testing at Los Alamos National Laboratory (LANL) and is being investigated for possible treaty monitoring applications requiring authentication of items such as warheads, reentry vehicle buses, and intercontinental ballistic missiles. It is also being adapted for characterization of chemical munitions to determine their contents. ARS is the more general form of the NDE technique known as resonant ultrasound spectroscopy (RUS)[3], also developed at LANL, but RUS utilizes only ultrasonic frequencies.

1. See for example *Ultrasonic Spectral Analysis for Nondestructive Evaluation*, D. W. Fitting and L. Adler, Plenum Press, New York, 1981.

2. "Acoustic Resonance Spectroscopy," D. N. Sinha, *IEEE Potential* 11(2), 10 (1992).

3. Aspects of the RUS are patented: "Resonant Ultrasound Spectroscopy," A. Migliori, Los Alamos National Laboratory, US Patent No. 5,062,296 (1991).

III. ARS EXPERIMENTAL METHOD

For more than a year, LANL researchers have been developing the ARS NDE approach for studying objects of varying size and complexity.[4] ARS exploits the fact that elastic solid objects, regardless of their shape or structure, possess many natural modes of vibrations. These vibrational modes are unique to that object and depend on the geometry (both shape and size), the elastic moduli, and various physical properties (such as densities and speed of sound in the materials) of the object. The object will resonate when it is mechanically excited at frequencies that correspond to any of these natural vibrational modes.

The ARS technique developed at LANL involves acoustically exciting a solid object by applying a swept-frequency voltage signal to a custom-designed piezoelectric transducer in physical contact with the object. Using a second transducer, the extremely small mechanical resonant vibrations of the entire object are recorded in real-time. The frequency of the sine-wave electrical signal is swept from a few kHz to several thousand kHz in approximately 10 to 20 seconds, although the sweep time and sensitivity can be varied. Because ARS takes advantage of the natural vibrational modes of the object, only about 1 milliwatt of excitation energy is needed to produce a relatively large vibrational response in most objects.

The object will vibrate at all excitation frequencies, but the vibrations become observable only when a resonance condition is reached. At other frequencies, the received signal is in the noise level and corresponds to movements of the object of 10 angstroms or less. At resonances, however, the amplitude of the induced vibrations can increase by more than two orders of magnitude and can easily be monitored by a sensitive transducer.

Because the acoustic signature is based on whole-body vibrations of the object and because amplitude information is secondary, the exact placement of the transducers on the object is not critical. The ability to position the transducers on the object at any accessible location significantly reduces the measurement constraints but may require that certain compensations be made in data analysis. Although the geometry and physical parameters of a complex object determine its acoustic spectrum, information on the actual shape and internal configuration of the object is not obtained through ARS.

Objects possessing one-dimensional geometries, such as rods and beams, have simple acoustic spectra comprising the fundamental resonance frequency and higher harmonics. (This is illustrated by the numerous modes of a vibrating string.) For two-dimensional objects, such as plates and disks, the spectra become much more complicated as additional vibrational modes (the overtones) are excited. Modal analysis techniques, which characterize the dynamic properties of an elastic structure in terms of its modes of vibration, can predict these modes with reasonable accuracy. For complex, three-dimensional objects, however, it becomes exceedingly difficult to predict the entire resonance spectrum. In reality, even for objects with geometries only slightly more complex than regular spheres or cylinders, no analytical solutions are possible, and numerical computer methods are needed to characterize the spectrum.

The distribution of frequencies of the measured resonant vibrations, which may number into the hundreds, is at some level unique to an object and provides an acoustic signature.

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4. Pulse-echo acoustic techniques are different from ARS in that they rely on a return acoustic signal (the "echo") to determine internal structure of the object being investigated. ARS, by contrast, cannot image an object *per se*. Pulse-echo techniques require exacting coupling between the acoustic transducer and the object under study.

Consequently, small variations in the object (shape, weight, internal composition, etc.) can be inferred from the resonance spectrum. For a more comprehensive acoustic signature, the amplitudes of the fundamental and lower frequency modes can also be used to characterize the object. The acoustic signature depends on the internal composition of the object and is thus sensitive to fill type and amount. Individual resonance modes are affected differently by the presence of fill material. Because of this, ARS can be used to monitor fill-level variations over time for a given item or to compare fill types and levels among several items of the same kind.

In ARS, the primary objective is not to determine the physical characteristics of an object or its contents *per se*, but to use the resultant complex acoustic resonance spectrum to

- compare the acoustic spectrum of the object under test to a reference spectrum to detect dissimilarities, variations, or flaws in the object;
- compare the acoustic spectrum of an object to itself at a later time to determine characteristics of tampering, substitution, aging, wear, etc.;
- record the acoustic spectrum of any complex object to generate a unique fingerprint for identification purposes;
- determine if a sealed object contains liquid or solid;
- determine fluid level inside a sealed container; or
- determine the number of identical objects inside a sealed container.

IV. ARS IN MONITORING OF CHEMICAL WEAPONS

Experiments employing ARS (along with several other NDE techniques) were conducted on chemical weapon (CW) munitions and other items at the Tooele Army Depot, UT in early 1991.[5] The purpose of the ARS experiments was to simulate CW verification measurements under realistic conditions and to determine the maximum expected variability in the measurements. Hence, no effort was made to optimize data collection or experimental procedures. Transducer placements were only nominally the same from one item to the next, and an acoustic coupling compound was not needed.

The following items were measured:

- 105-mm shells filled with nerve agent GB, some while in pallets;
- 155-mm shells filled with high explosives (HE) or with nerve agents GB or VX, some in pallets;
- M106 HE-filled shells;
- one-ton containers filled with Mustard agent or water; and

5. *Verification Technologies*, First Quarter 1992, "Chemical Weapons Verification;" and "Nondestructive Evaluation Tests on Chemical Weapons and Containers at Tooele Army Depot, Final Draft," A. M. Preszler, Ed., Department of Energy report DOE/ID-10346, July 1991, pp. 259-294.

- empty and surrogate-filled 105-mm and 155-mm shells.

In all, approximately 300 spectra were taken on more than 110 items.

Experimental Results. An important question in ARS verification is the extent to which transducer placement affects the acoustic spectrum. Therefore, measurements were made to determine the degree of variation one can expect in spectra if the transducers are not placed in exactly the same location on a munition. Tests were made with transducers at two configurations representing extreme differences in positioning. The data indicate that the transducer position influences the *amplitude* of some of the resonant vibrations, but the characteristic *frequencies* remain unaffected. Similarly, measurements on munitions in pallets versus measurements of the same items placed on the floor show that there is no change in the frequency distribution of the spectra. For a given item, acoustic spectra are highly repeatable. It should be pointed out that in the ARS technique frequencies, not amplitudes, are the primary parameters of interest.

The question of repeatability of measurements under different excitation conditions is also an important consideration because of possible noncontact measurement systems where both the transmitter and the receiver are replaced by remote systems. Preliminary results from Tooele indicate that remote, audio excitation using a 2" speaker provides spectra that are identifiably the same as those excited with a transducer when frequencies are compared.

Comparability of Similar Items. One of the most important issues addressed by the Tooele experiments is comparability. For ARS to be useful, measurements on similar objects should produce similar acoustic signatures so that they can be identified as belonging to the same class or group. The results should not be strongly influenced by the nature of the measurement or by the storage conditions of the objects, for instance, whether the munitions are stored in their pallets or lying loose. Fig. 1 shows acoustic spectra for six 105-mm GB-filed shells. The data are superimposed in the figure, and the comparability of the data is clearly evident. Although there are the expected minor variations in the amplitudes from one item to the next, the frequencies match very well.

Measurements on two pallets of 155-mm HE-filled rounds, eight rounds for each pallet, likewise showed that the averaged spectra for each pallet was nearly identical in regard to frequency. While some peaks were not well resolved, their characteristic frequencies were still identified. Simple pattern recognition algorithms could easily determine the average spectra for the two pallets to be the same.

Measurements on the GB- and HE-filled shells demonstrated the inherent comparability and consistency of the spectra. Within a given class of objects tested, the acoustic signatures are consistent and identifiably the same.

Effect of Fill Material on Acoustic Signature. Besides comparability, the ability of the technique to distinguish the fill material, such as solid versus liquid or between different liquids, is of importance. Measurements were made on munitions filled with solids (Comp B and TNT explosives, as well as sand) and on munitions filled with GB and VX liquid agents. Fig. 2 shows a typical result from a sand-filled munition (solid line) compared with a surrogate liquid-filled item of the same class (dashed line). Besides a shift in the frequency of the fundamental resonance peak near 6 kHz, the higher frequency components are damped for the solid. Where solid fills are well packed, the spectra are characterized by a relatively flat response in the high frequencies. This typical response is clearly distinguishable from the spectra of liquid-filled items where there are many high-frequency, higher-amplitude components present in the spectrum.

Although not shown in Fig. 2, the resonance peaks are much sharper for liquid-filled munitions than for solid-filled. This fact, in itself, can be used to differentiate between solid-

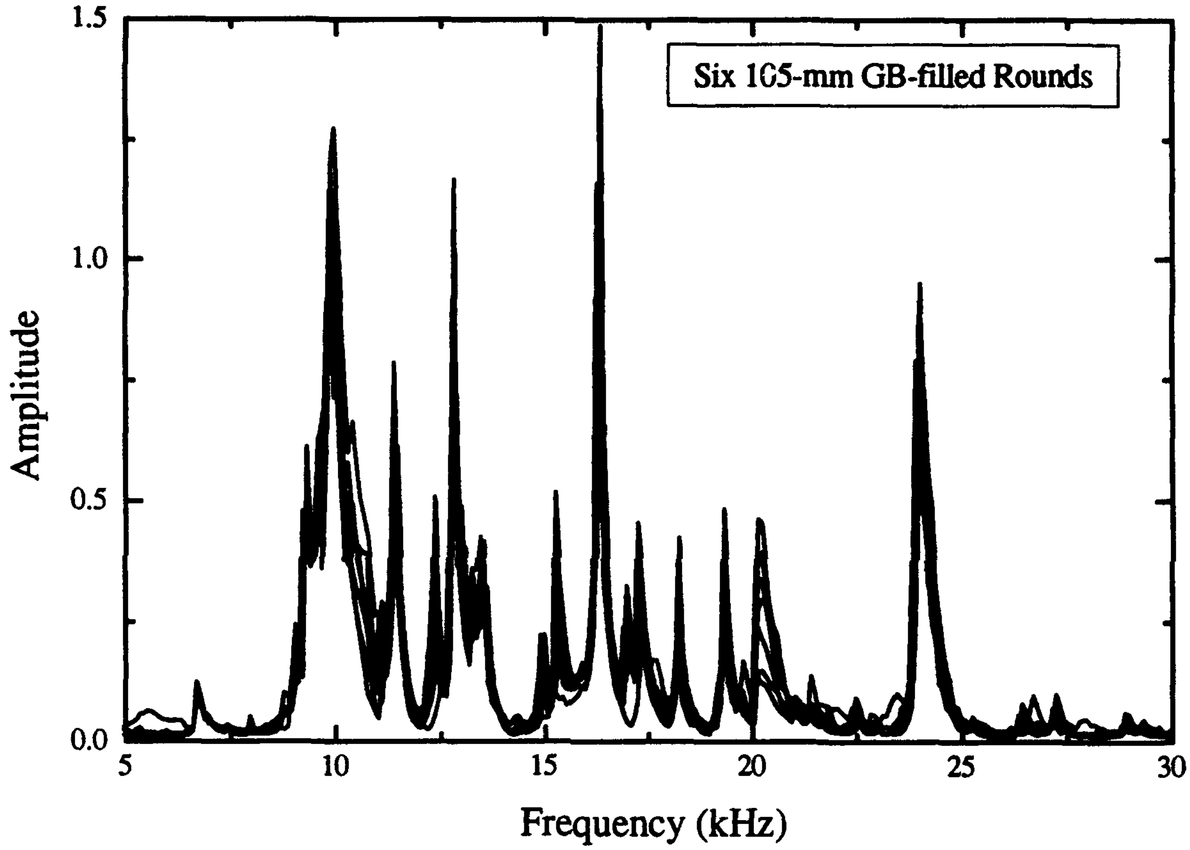

Figure 1. ARS measurements of six 105-mm GB-filled artillery shells. Spectra are superimposed to show the excellent comparability between ARS measurements of items within the same class.

and liquid-filled munitions without requiring initial calibration.

Measurements on different solid-filled M106 rounds indicate that TNT-filled items are easily distinguished from those filled with sand. Both types showed the typical results as mentioned above. Comp-B filled shells showed similar results, but several shells gave anomalous, but repeatable, data. This is most likely caused by the tendency of Comp B to detach from the inner walls of the shell and form voids, cracks, and cavities. The TNT fill, in comparison, is more tightly packed. Nevertheless, the lack of sharpness of peaks for Comp B agreed with expectations for solid-fill objects.

The effect of different types of liquid fill was readily discernible in the acoustic spectra. A surrogate-filled and a GB-filled 105-mm shell had obvious differences. These differences in frequency distribution result primarily from the fill material and not from differences in the actual shell casings. (Previous results such as those shown in Fig. 1 demonstrate that similar shell types give similar spectra when filled with the same liquid.)

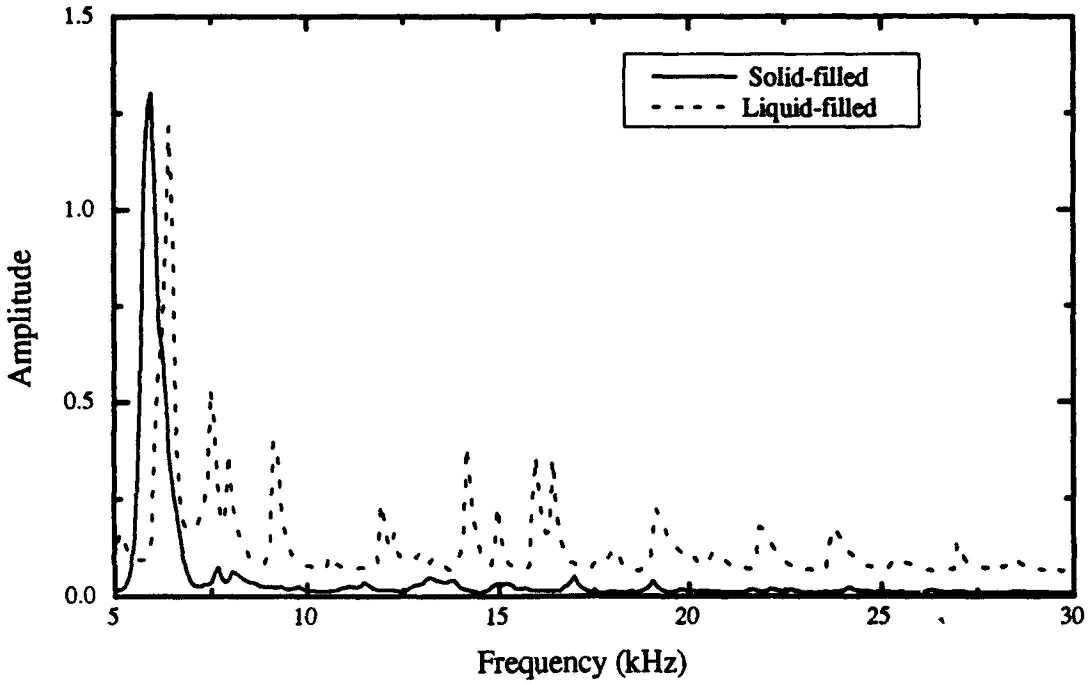

Figure 2. AKS spectra for two different 155-mm artillery shells, one filled with ethylene glycol surrogate and the other with sand. The spectra are discernibly different because of the fill material.

When measurements were made on 155-mm rounds filled with different materials (GB, VX, and HE), the consistency of the data for the same type of material was readily observable. Averages of the measured spectral patterns can be used as general templates for a specific type of material. In other words, we expect that results from any 155-mm GB-filled round should fit within the template derived from the average of other measurements on the same item, particularly when the template gives primary importance to frequency and not to amplitude. If there are significantly different manufacturing specifications in 155-mm rounds, however, one might see different characteristic frequencies.

V. ARS IN MONITORING STRATEGIC MISSILES

We are currently exploring the applicability of the ARS technique to large items such as strategic missiles as covered by the START or INF Treaty.

Preliminary ARS Measurements on Missiles. Preliminary ARS tests were carried out on a Minuteman III Stage III Ground Test Missile (GTM) motor at Hill Air Force Base in June 1991. Also tested was another missile motor, a Minuteman Stage II motor attached to a Stage I motor. The objectives of the tests were to (1) determine the extent to which we could excite resonances in the missile motors using our custom designed transducers, and (2) establish a test plan for a more definitive set of experiments on actual missiles.

Spectra were taken with transducers clamped to the forward skirt of the GTM at three different locations that were within 12 inches of each other, with the two transducers (transmitter and receiver) positioned near the opposite edges of a quadrant around the perimeter of the skirt. Repeatability of the data degrades if the transducers are moved to very different locations (i.e., farther than 12 inches). If all the measurements are made near any arbitrarily chosen position (around any given quadrant), then the reproducibility of the data is excellent and the acoustic signature easily identified. Although, we could not excite vibrations in the underlying missile shell through the outer cork layer, the extreme sensitivity of the transducers—even when attached to the cork—allowed detection of vibrations generated in the missile motor by other means.

Minuteman III Stage III missile motors cannot be excited efficiently by direct transducer contact with the outer surface because of the missile's cork covering. For missiles that are covered with harder materials like fiberglass or Avcoat, however, it is possible to excite resonances by direct-contact transducers and by remote excitation using speakers. Moreover, the use of fiberglass and similar materials in the missile construction means that vibrations are not efficiently propagated along the length of the missile. Thus, it is difficult to obtain an acoustic signature that represents the entire missile motor. Localized information is obtainable, however, and very reproducible data are obtained if all measurements are made in the same general area on a given component of the motor.

It appears from this preliminary set of data that if measurements are made at two or more critical locations on a missile motor (for instance, on the forward skirt and the raceway channel), then the combined information may provide sufficient information to reliably identify (a) a given class of missile motors and (b) an individual missile motor. But clearly, more systematic measurements on several missile motors of the same and different types are needed to reach conclusions on the suitability of ARS to large TLIs.

Current Plans for Missile Testing Using ARS. ARS testing plans are now being implemented to answer questions posed by the preliminary measurements conducted at Hill Air Force Base. Our overall objective is to determine if the technique can effectively identify—from the acoustic resonance spectrum alone—a class of missile motors in various storage configurations. A related objective is to determine if individual missile motors can be uniquely identified from their acoustic signatures. Specific questions to be addressed include the following:

- ❑ Do missile motors of the same type have similar acoustic spectra that can be easily identified?

- Do different motor types provide discernibly different spectra?
- Are there spectral features unique to the whole item or are only regional signatures obtainable?
- Are the measurements reproducible, and what effect do small variations, such as manufacturing tolerances, have on the signature?
- What effect does changing the missile configuration (e.g., removal of the nozzle) have on the acoustic spectrum?
- What transducer positioning and coupling to the missile motor are necessary for reproducible results?
- What kind of excitation and transducers would be needed for larger structures such as Peacekeeper missile motors?

The program will proceed with a combination of the experimental measurements described above, computer and physical scale modeling, and acoustic signature analysis. The numerical modeling predictions will be used to optimize the excitation and measurement procedures and to direct the signature analysis. These experiments are currently underway and will be reported at a later time.

VI. CONCLUSIONS

The tests at Tooele on CW items provided an excellent opportunity to assess the capabilities of the ARS system in a realistic setting for CW verification. The system was able to distinguish between otherwise identical items filled with different materials, e.g., liquids versus solids, and between different liquid fills, such as VX and GB nerve agents. For lots of similar items (e.g., munitions that have the same fill and dimensional specifications), ARS provided demonstrably similar spectra for each item of the lot. Further, by analyzing individual spectra in more detail and with proper calibration, conclusions can be drawn concerning the fill level of an item. Individual measurements are highly repeatable, particularly with regard to resonance frequencies, the critical measurement parameter of the technique. Thus, the ARS can be used to screen large numbers of items for their fill type and internal structure. In such applications, ARS would prove most useful when combined with other NDE techniques and, perhaps, sampling and analysis methods for calibration purposes.

There are numerous advantages of the ARS system in CW verification applications:

- provides strong evidence regarding the authenticity of stockpile declarations, particularly regarding detection of anomalies in large populations of items;
- nonintrusive, repeatable measurements that do not image an item or its contents;
- portable measurement apparatus;

- ❑ field systems can be engineered to be extremely reliable and easy to operate, requiring minimal operator training;
- ❑ short measurement times, typically less than one-half minute, and equipment setup times of a few minutes;
- ❑ no sample preparation required;
- ❑ *in situ* measurement capabilities, e.g., items could be measured without moving them from their storage configurations in pallets or racks; and
- ❑ a permanent, digitized record of the spectral measurements.

ARS is particularly well suited for CW stockpile verification scenarios such as might be needed in the CWC or the bilateral reduction agreement between the United States and the former Soviet Union. In this application, ARS, together with other complementary methods, could be used in an analytical hierarchy in which successively more definitive (and intrusive) analyses are conducted on a progressively smaller sampling of items. Ideally, each method would be designed to detect a particular kind of anomaly, such as weight discrepancy, erroneous elemental composition, or atypical acoustic signature. Such an hierarchical approach makes use of a statistical sampling strategy for anomaly detection and provides a verification confidence that is much higher than would be obtained by any of the analytical methods employed singly.

The first level of the hierarchy might employ visual inspection and counting of items in order to compare the stockpile with recorded declarations. While the authenticity of the items is not confirmed and item counting can be easily spoofed, this level might provide some degree of verification assurance. If more conclusive verification is needed, the next level of the hierarchy could employ ARS to measure a large number of items to confirm that they have the same fill material—without necessarily characterizing that material—and to detect anomalies. The next higher level might involve weight determinations for a selected sampling of items. In addition to simple gravimetric methods, acoustic pulse-echo methods could be used to determine fill levels.

At higher levels of the hierarchy, methods could determine elemental composition (perhaps by using neutron-activation-based NDE). The final and most conclusive level of the hierarchy would be to determine chemical composition through destructive chemical sampling and analysis. This might occur at the time of stockpile verification or much later at the time of agent destruction, depending upon the verification requirement. But because of the time, cost, and hazards associated with this level, only a very small percentage of the verified population could be subject to chemical analysis during the stockpile verification phase.

The strength of this hierarchical approach lies in the fact that a very large percentage of items are measured with the simpler techniques, while only a smaller number are subject to the more time consuming and complicated analytical procedures. In such an analytical hierarchy, ARS would provide a proven method to authenticate a large number of items regarding their similarity and, particularly where calibration exists, their content type and fill level. The ARS method can provide this monitoring information with high confidence, yet would not incur penalties in time, cost, or intrusiveness. Although there are many technical as well as policy issues to be resolved, ARS could provide an important tool for authenticating the large numbers of items expected to be covered by chemical weapon agreements.

Conclusions regarding ARS in monitoring large treaty-limited items cannot be made at this time. The current ARS program of physical measurement, modeling, and acoustic signature analysis on ICBMs will provide necessary information to determine the technical feasibility of applying ARS to items such as those captured by the START or the INF Treaty. ❑

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Using Gravity to Monitor Arms Control Treaties

J. Parmentola, S. Gray, R. LeSchack
The MITRE Corporation

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I. Measuring Up to Some Arms Control Verification Issues

The number of monitoring tools available to those concerned with arms control verification problems has been rapidly growing over the past few years. The problem facing the policy analyst and decision maker concerned with arms control verification issues is how to choose among the various monitoring systems and verification tools that are available. This is not simply a matter of recognizing that the detection of a particular characteristic of a treaty limited item with some monitoring technology is appropriate for a specific arms control verification problem. There are many more issues to consider, many of them political in nature. Nevertheless, there are important technical issues which, when properly analyzed, can provide the policy analyst and ultimately the decisionmaker with some substantive policy guidance in narrowing down choices. For example, ideally, a monitoring system used for arms control verification should:

1. be non intrusive;
2. limit the number of false alarms almost to zero;
3. be very difficult to spoof;
4. minimize interference with normal operations;
5. be easy to use by nontechnical personnel;
6. be reliable and easy to maintain;
7. and be affordable.

All monitoring systems have their pluses and minuses when measured against this list of criteria. X-ray monitoring systems can be highly intrusive because they can reveal design details of treaty limited items, however they can detect certain dimensional features within objects with a relatively high degree of confidence. This technology is also very mature, so there is a long history of experience associated with operating and maintaining it.

The passive detection of neutrons or gamma rays from nuclear warheads, which contain radioactive materials, can provide some information about their design. However, neutron or gamma ray detectors can verify the presence of nuclear materials with high confidence provided the corresponding background radiation is relatively low. Similar kinds of tradeoffs can be delineated for other monitoring systems. The bottom line is, nothing is ideal, however due consideration of tradeoff analyses can provide substantive policy guidance to decision makers who have to deal with the more complex political problems associated with arms control verification.

A group of us at The MITRE Corporation have been studying a number of novel applications of a rather remarkable device called a gravity gradiometer.[1, 4] To better appreciate what this device does, it is useful to review some basic notions of gravity. For example, the weight of an object is a result of a force exerted by the earth on the object. This phenomenon gives rise to the concept of a gravitational field (in more terse terms, gravity) produced by the earth or for that matter any object having mass. In other words, the mass[5] of the earth produces a gravitational field which interacts with the mass of an object to produce a force which is the object's weight. Similarly, the object's mass produces a gravitational field (very much smaller than the earth's) which interacts with the earth's huge mass to produce a force on the earth which is equal in magnitude, but opposite in direction. The gravitational field produced by an object permeates all space and decreases according to the well known inverse square law. It accounts for the motion of the planets and the formation and motion of the galaxies throughout the universe.

For most massive objects, for example ourselves, such gravitational effects are very small. The gravitational force exerted by one person on another or by a piece of furniture on a person is relatively feeble. However, over the past eighty years or so scientists and engineers have developed technologies which can measure these feeble effects with incredible accuracy. The quantity of particular relevance to the gravity gradiometer is a gravity gradient which corresponds to a change in gravity (in more precise terms, the gravitational field) divided by the distance over which that change occurs. If the change in gravity is very small over relatively long distances then the gravity gradient is relatively small. On the other hand, if the change in gravity is large over relatively short distances, then the gravity gradient is relatively large.

Since the turn of the century, gravity gradiometers have been used for oil and mineral exploration. Very massive underground deposits of oil and minerals can produce relatively large gravity gradients compared to those associated with standard underground geology. Such measurable differences can be used to locate likely areas for exploration of these important natural assets. This technology has also been used to improve the inertial navigation of aircraft, submarines, and missiles. Standard inertial navigation systems lack detailed information about the earth's gravitational field which can produce guidance errors. A gravity gradiometer can measure these subtle effects in real time and in conjunction with an inertial navigation system, improve the inertial navigation of mobile platforms, especially over long distances. Three such devices, produced by Bell Aerospace, are currently in operation, one on a U.K. Vanguard class submarine and two on U.S. Trident class submarines. They have also been used to measure gravitational effects produced by the local environment around missile silos. This information is incorporated into the inertial navigation system of a missile in order to minimize launch point errors.

In thinking about the employment of this sensor for verification applications, we have used the above criteria as a guide for evaluating its merit as an arms control verification tool. As a result of our technical analysis, we have come to some potentially important and interesting conclusions about the utility of this device as a verification tool. So far, we believe that an appropriately designed gravity gradiometer could:

1. distinguish between dual capable weapon systems; i.e., nuclear and conventional variants of a weapon;

2. count the number of warheads on an ICBM or SLBM;

3. distinguish between high-explosive and chemically armed artillery munitions of the same dimensions and weight;

4. and it is theoretically feasible that it could be used as a highly accurate portable weighing system.

In all these applications, we believe that this technology satisfies the above criteria reasonably well. In order to appreciate this conclusion, it is important to understand the underlying physical phenomenon that enables gravity gradiometers to be useful in verification applications.

All objects have mass and associated with this mass is a mass density[6] (mass per unit volume). This physical quantity can vary quite significantly from point to point inside an object. For example, there might be an empty space (almost zero mass density, because of air in the space) inside a weapon, but just right next to it a very massive nuclear warhead which has a relatively high mass density. Ideally, we could use an object's mass density to identify it with very high confidence, if we could measure it at each point in space within the object.[7] On the other hand, we probably would not want this amount of detail, since it would provide rather sensitive information.

An alternative is to measure local gravitational effects (at points in space around the outside of the object) produced by the object's mass density. Intuitively speaking, the higher the mass density within a certain region of an object, the more intense are the gravitational effects in the vicinity of this region. For example, if gravitational effects were measured at points along a line parallel to the axis of a missile at some distance away from the missile's surface, the actual measured values would be sensitive to the distribution of mass within the missile. If more mass were concentrated in one section of the missile (higher mass density) relative to another (lower mass density), then gravitational effects would show greater strength at points in space which are close to the higher density region and less strength at points near the low density region. The output of a scan of a missile with a gravity gradiometer would result in a gravity gradient profile or template which would have a large amplitude in regions where the mass density is high and relatively low amplitude in less dense regions. An example involving simulated gravity gradient profiles (computer generated from realistic numerically specified mass densities) for cruise missiles (U.S. Tomahawk) is presented in figure 1. The vertical axis is the radial gravity gradient (pointing outward and perpendicular to the missile's axis) measured in Eotvos units.[8] The horizontal axis is the distance along the axis of the cruise missile. In this case, the nuclear cruise missile has a high density warhead located toward the front end of the missile and a large quantity of less dense fuel behind it. The conventional version is much less dense in the front end, but has a higher density in the aft section (of the front end) of the missile due to the conventional warhead. These features are clearly visible in the simulated gravity gradient profiles of the two missiles. Figure 2 shows how the difference between the gravity gradient profiles of the two versions becomes less pronounced as the scans are made further from each missile. This feature provides an indication on how to control the resolution of the device.

These graphical plots suggest that gravity gradiometer measurements are a relatively nonintrusive way of verifying the identity of an object. The measurements are purely passive and the resolution (the discernible spatial dimensions of the bumps and dips associated with massive elements inside an object) can be controlled by the distance at which a scan is made. As long as the measurements are made at sufficiently close distances, there will be enough detail to enable the gravity gradiometer to make positive identifications, unless an object has a mass density distribution which is almost identical to another object.[9]

It is also difficult to spoof gravity gradiometer measurements, because there are actually five independent gravity gradients (figures 1 and 2 indicate only one of the five) that can be measured simultaneously. Each of the five gravity gradients is sensitive to a different aspect of an object's mass density. In order to spoof the gravity gradiometer, it would be necessary for an adversary to modify the mass density distribution such that all five gravity gradients at each point in space were affected in a precise way. This is not easy to do in practice, especially for complex weapon systems. Furthermore, mass cannot be shielded. If a quantity of mass is added or subtracted from an object, the corresponding modifications will show up in gravity gradient measurements.

The time it takes to make a gravity gradiometer measurement depends upon the level of accuracy that is required. The longer the measurement time, the more accurate the measurement. A realistic ballpark figure for a reasonably accurate measurement (one Eotvos unit accuracy) at one point in space is roughly ten seconds. In figures 1 and 2 the number of simulated measurement points was sixteen which translates into about three minutes of measurement time. In an actual monitoring situation the missile would be placed on a mobile platform which would be guided on a rail and the gravity gradiometer would be stationary. Measurements would be made as the missile on the platform passed by the device at some specified rate. In this case, a gravity gradiometer would have a relatively small effect on cruise missile production operations, even if the measurement time at each point in space was two or three times as great as the estimate specified above.

There is evidence that currently deployed systems involving gravity gradiometers can be made user friendly and this lends support to the belief that the same level of capability can be achieved for gravity gradiometers designed for arms control verification applications. As mentioned above, gravity gradiometers are currently in operation on three submarines for inertial navigation. These remarkable devices, which are produced by Bell Aerospace, are actually a part of a system (including power supplies, computer boards, batteries, etc.) which has been designed for easy use. Bell has gone to great lengths to make this particular system user friendly. A computer terminal serves as the command and control center. The computer screen uses windows and menus, all involving displays which are easy to understand, to allow the user to ask questions of the operational state of the system. If there is a malfunction, the screen will indicate the precise nature and location of the problem.

There is also evidence that currently deployed systems for inertial navigation have been designed for reliability and ease of maintenance. When problems arise the command and control station indicates the precise nature of the problem and the modular nature of the system components allows the user to simply replace the defective part in real time. Again, there is no reason to believe that similar levels of capability cannot be achieved for gravity gradiometer systems designed for arms control verification applications.

One potential drawback to the gravity gradiometer might be cost. Current systems are packaged for inertial navigation applications and Navy specifications require the system to be rugged beyond what is actually required for arms control verification applications and are therefore expensive. Bell Aerospace has indicated that it can produce a gravity gradiometer system for verification applications which can be put into two fifty pound boxes and carried by four military personnel. The price tag for such a device would roughly be three hundred thousand dollars.[10]

II. Some Gravity Gradiometer Activities

MITRE's efforts in exploring the use of gravity gradiometers for verification applications has largely focused on establishing requirements for these devices. Our technical analyses so far indicate that gravity gradiometers have the capability of contributing to a number of verification problems. The noninstrusive nature of the measurement process and the formidable difficulty of spoofing the device make it an attractive choice for verification applications. While our conclusions are based upon theoretical analyses, the underlying physical principles have been well-understood for hundreds of years.

The next step in achieving further confidence in the capability of a gravity gradiometer in verification applications is to perform a demonstration. System Planning Corporation (SPC), under contract to the DNA and in collaboration with the University of Maryland, has undertaken such an effort.[11] The University of Maryland has developed a gravity gradiometer[12, 13] (with support from NASA) for the purpose of making fundamental gravity measurements of the earth from space. SPC is currently building actual physical models of a conventional and a nuclear cruise missile based upon some early work by one of us.[1, 3] They will place each physical model on a mobile platform which will pass by the University of Maryland gravity gradiometer at a certain rate. The measurements will be processed and recorded as gravity gradiometer profiles or templates. The results should be consistent with the predictions in figures 1 and 2.

III. Future Prospects

There is some indication that the Defense Nuclear Agency might fund at least one contractor (maybe two) gravity gradiometer manufacturer over the next year or so. This work may involve some further demonstrations of current gravity gradiometer capability with respect to arms control verification applications. If these demonstrations turn out positive, then follow-on work might be directed toward developing a mission specific verification prototype for demonstrations in the field. If all this works out technically, as it should, in the near future we may eventually see a properly packaged and tested gravity gradiometer in the field. For those who are believers in this technology and have worked hard to bring it this far, such an accomplishment would be a very exciting and satisfying achievement.

IV. References and Footnotes

1. John A. Parmentola, "The gravity gradiometer as a verification tool," Science and Global Security, 1990, Volume 2, pp. 1-15.

2. John A. Parmentola, "New tools for SLCM verification, "published as a Center for International Security and Arms Control working paper, December, 1989.

3. John A. Parmentola, "Distinguishing between nuclear-and conventionally-armed cruise missiles with a gravity gradiometer," published in the proceedings of the 17th Gravity Gradiometer Conference, Hanscom Air Force Base, Bedford, MA, October, 1989.

4. Bell Aerospace, Draper Laboratories, and Hughes Aircraft have developed gravity gradiometers for inertial navigation. For a brief introduction to these different designs see, Mark A. Gerber, "Gravity Gradiometry," Astronautics & Aeronautics, May 1978, pp. 18 - 26.

5. The notion of mass and weight are sometimes confused. The weight of an object is directly related to a force acting on the object, however mass is an intrinsic property of an object. So a lead ball may weigh 100 pounds on earth and have a certain mass, however on the moon it would weigh 1/6 less, but still have the same mass. To determine the mass of an object on the earth simply determine the weight by putting it on a scale and divide by the acceleration produced by the earth's gravity (32 ft/sec^2). On the moon, you would simply determine the weight of the object on the moon and divide by the acceleration produced by the moon's gravity. The resulting numerical quantity in both cases is the same and it is the mass of the object.

6. Mass density is a bit more complicated a quantity. An ordinary golf ball and a golf ball filled with lead have the same volume, but very different mass densities. There is much more mass in a lead golf ball than the ordinary one so its mass density is much greater.

7. There are some simple approaches to this problem which are nonintrusive, but unfortunately they do not provide enough information about an object's mass density. For example, one could weigh an object and thereby determine its total mass. If we know the dimensions of the object, we then can determine its average mass density by dividing by the object's volume. However, objects can have the same external appearance and be different internally while still having the same total mass and average mass density. By measuring the center of gravity or mass (for example, the point about which a seesaw is balanced with two kids on it), it is possible to distinguish between some objects that weigh the same and have the same external appearance. The center of mass of an object may not be the same as its geometrical center. This might indicate that an object has more mass to the left of its geometric center, than to the right. However, it is still possible to have two objects with the same weight, the same appearance, and the same center of gravity or mass, but still be different internally. One can make further progress by hanging an object at a point and allowing the object to swing in the earth's gravitational field (just like the pendulum of a grandfather's clock). This results in a measurement of an object's "tick" which is sensitive to its mass density. This still does not solve the problem, since objects having the same external appearance, mass, center of gravity or mass, and "tick" (more technically, the same moments of inertia) can still differ internally. To really know an object's mass distribution in detail would require relatively intrusive methods of measurement.

8. There are a number of ways of thinking about the physical significance of this unit. Numerically, its value is 10^{-9} sec^{-2} which is equivalent to the units of acceleration divided by distance. One way of appreciating this rather obscure unit is to consider a change in gravity of one part in a hundred billion times g (where g is the acceleration due to gravity which is 32 ft/sec^2 or 980 cm/sec^2) in 10 centimeters. In mathematical terms this translates into a change in gravity given by

$$\Delta g \cong 10^{-11} g \cong 10^{-11} \times 10^{3}\ cm/sec^2$$

$$\cong 10^{-8} cm/sec^2$$

$$\Delta g/10cm \cong 10^{-9} sec^{-2}$$

which is one Eotvos. This unit is also approximately equivalent to the gravity gradient produced by ten grains of sand at a distance of one centimeter from the gravity gradiometer.

9. To appreciate how this might be done, imagine an actual monitoring situation where truth data in the form of templates for a set of treaty limited items might be stored in a computer memory. When a gravity gradiometer scan is made of a particular treaty limited item, the processed data from the scan would be subtracted point by point from a corresponding stored template. If the result is not close enough to zero (some reasonable limits will have to be set), then a possible violation might be taking place.

10. Private communication, Ernest Metzger, Bell Aerospace, Buffalo, New York.

11. Private communication, Monte Chawla, System Planning Corporation, Arlington, Virginia.

12. Ho Jung Paik, "Superconducting Tensor Gravity Gradiometer for Satellite Geodesy and Inertial Navigation," The Journal of the Astronautics Sciences, Vol. XXIX, No.1, pp. 1-18, January - March 1981.

13. H.J. Paik, E.R. Mapoles, and K.Y. Wang, "Superconducting Gravity Gradiometers," Proc. Conference on the Future Trends in Superconductive Electronics, Charlottesville, Virginia, 1978, pp. 166-170

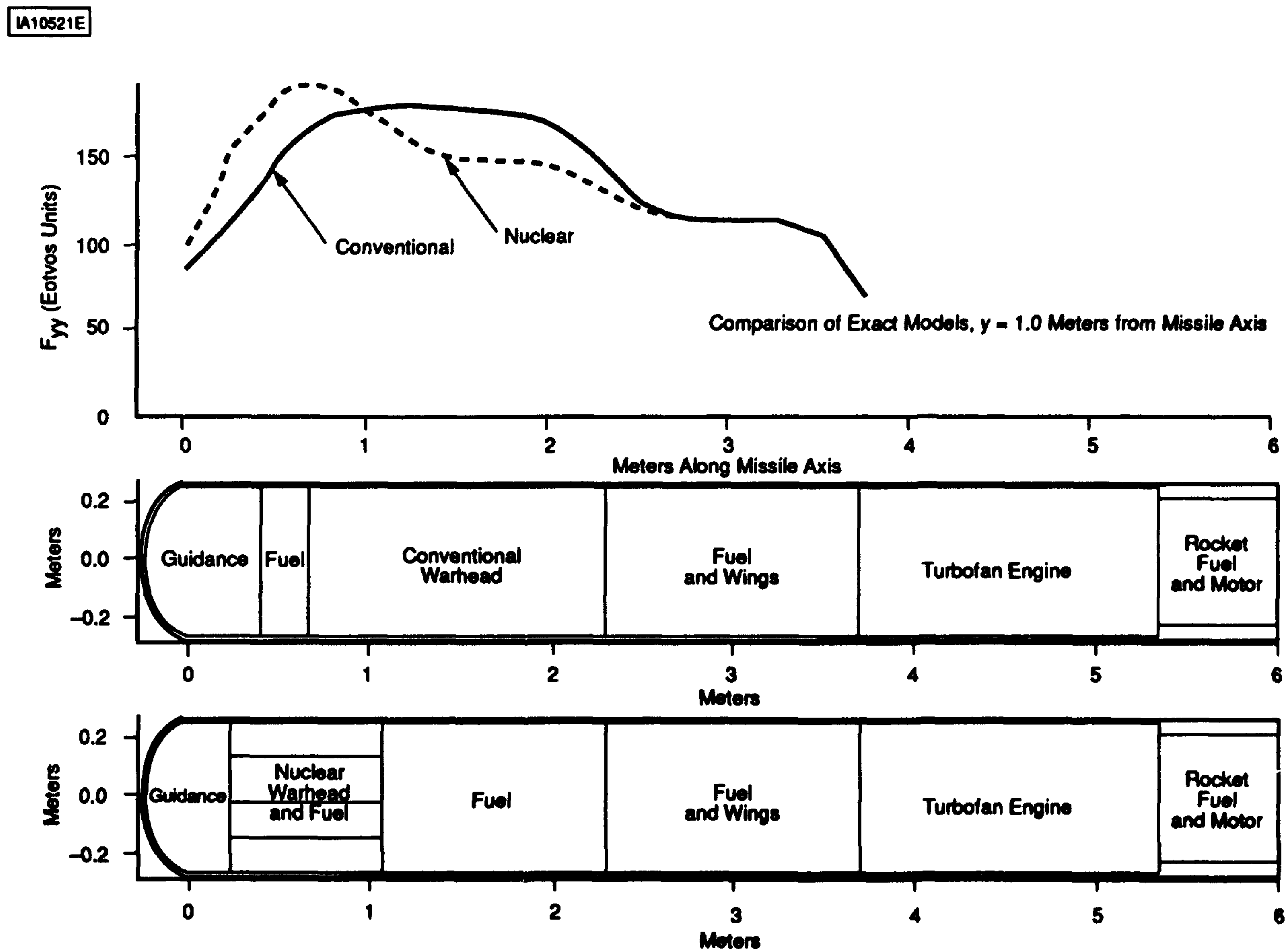

IA10521E
Fyy (Eotvos Units)
Conventional
Nuclear
Comparison of Exact Models, y = 1.0 Meters from Missile Axis
Meters Along Missile Axis
Guidance
Fuel
Conventional Warhead
Fuel and Wings
Turbofan Engine
Rocket Fuel and Motor
Meters
Nuclear Warhead and Fuel
Fuel

Figure 1.

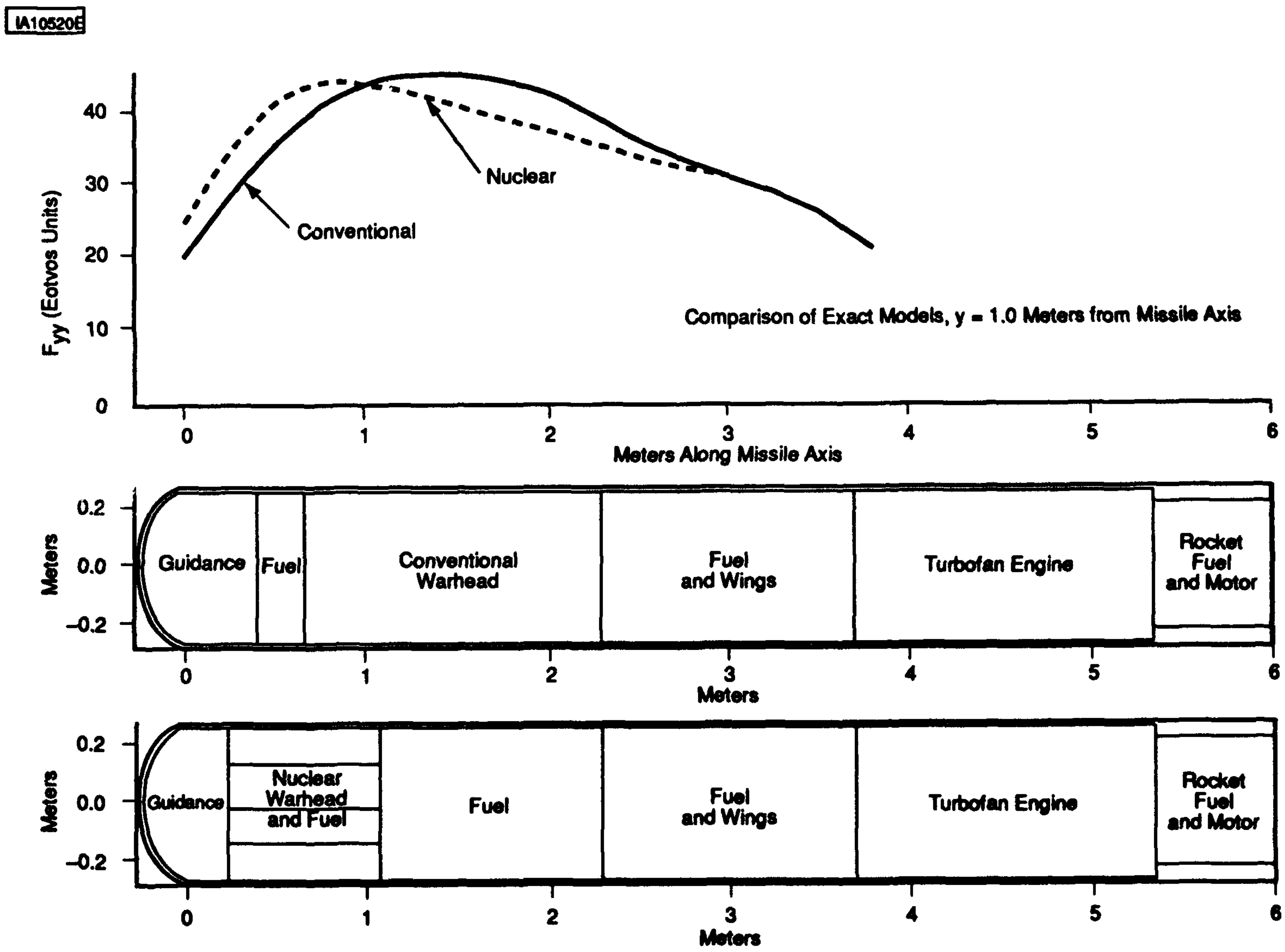

IA10520E
Comparison of Exact Models, y = 1.0 Meters from Missile Axis
F_{yy} (Eotvos Units)
Meters Along Missile Axis
Conventional
Nuclear
Meters
Guidance
Fuel
Conventional Warhead
Fuel and Wings
Turbofan Engine
Rocket Fuel and Motor
Guidance
Nuclear Warhead and Fuel
Fuel
Fuel and Wings
Turbofan Engine
Rocket Fuel and Motor

Figure 2.

Tag and Seal Systems Evaluated for Treaty Verification

M. Fischer
BDM International

Prepared for:
Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

The Importance of Tags and Seals

Tags and seals have been examined for possible use in treaty verification because of their potential to:

Increase confidence, transparency, and traceability

Decrease time, manpower, and costs

Desirable Attributes

Indication of transfer/tampering

Compatibility with TLI

Ease of operations

Concept simplicity

Minimum power requirements

Remote read capability

Environmental stability

Counterfeit resistance

Durability

Reasonable cost

Non-intrusiveness

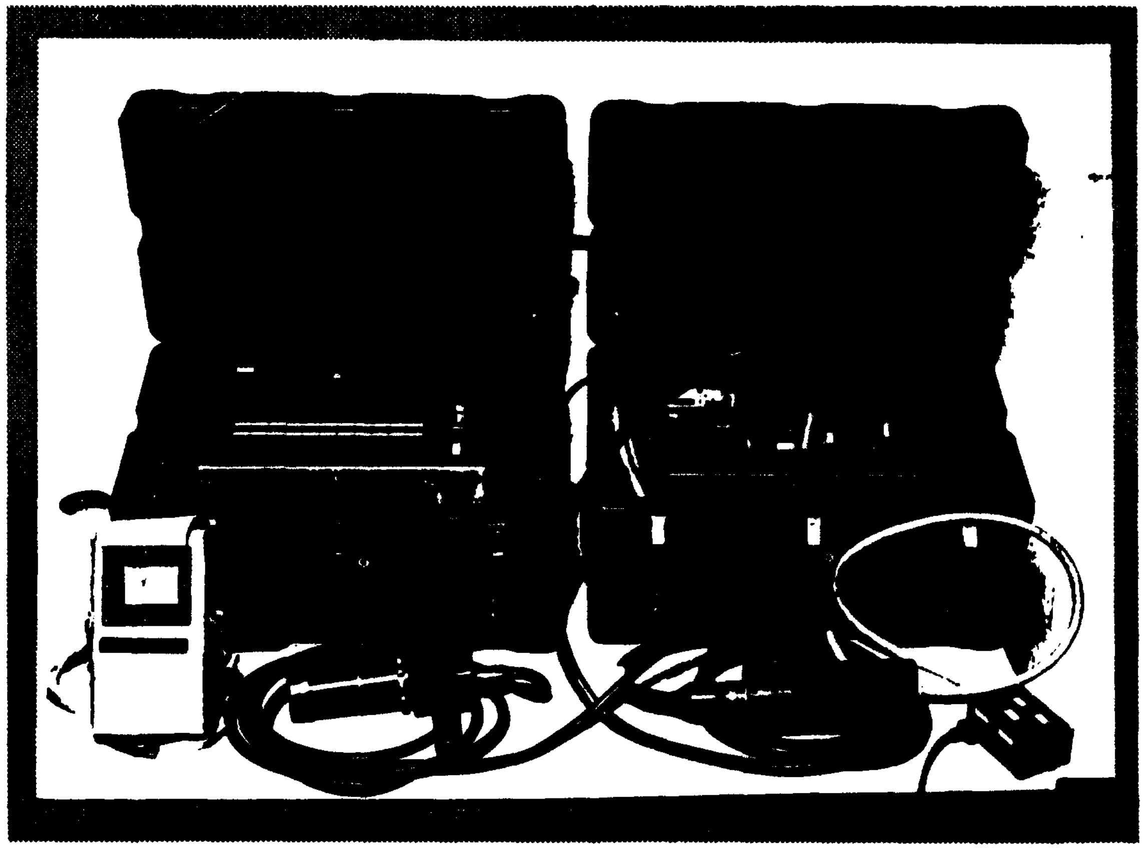
Lightweight

Automated data acquisition

Transferable technology

Reflective Particle Tag (RPT)

RPT Tag



RPT Reader System

Reflective Particle Tag (RPT)

Developed by Sandia National Laboratories

Security principle:

Randomly distributed micaceous hematite particles bonded to the tagged item, when illuminated by varying light angles, generates a unique, repeatable, non-counterfeitable signature. The thin, brittle adhered tag cannot be removed without destroying the signature.

Potential applications:

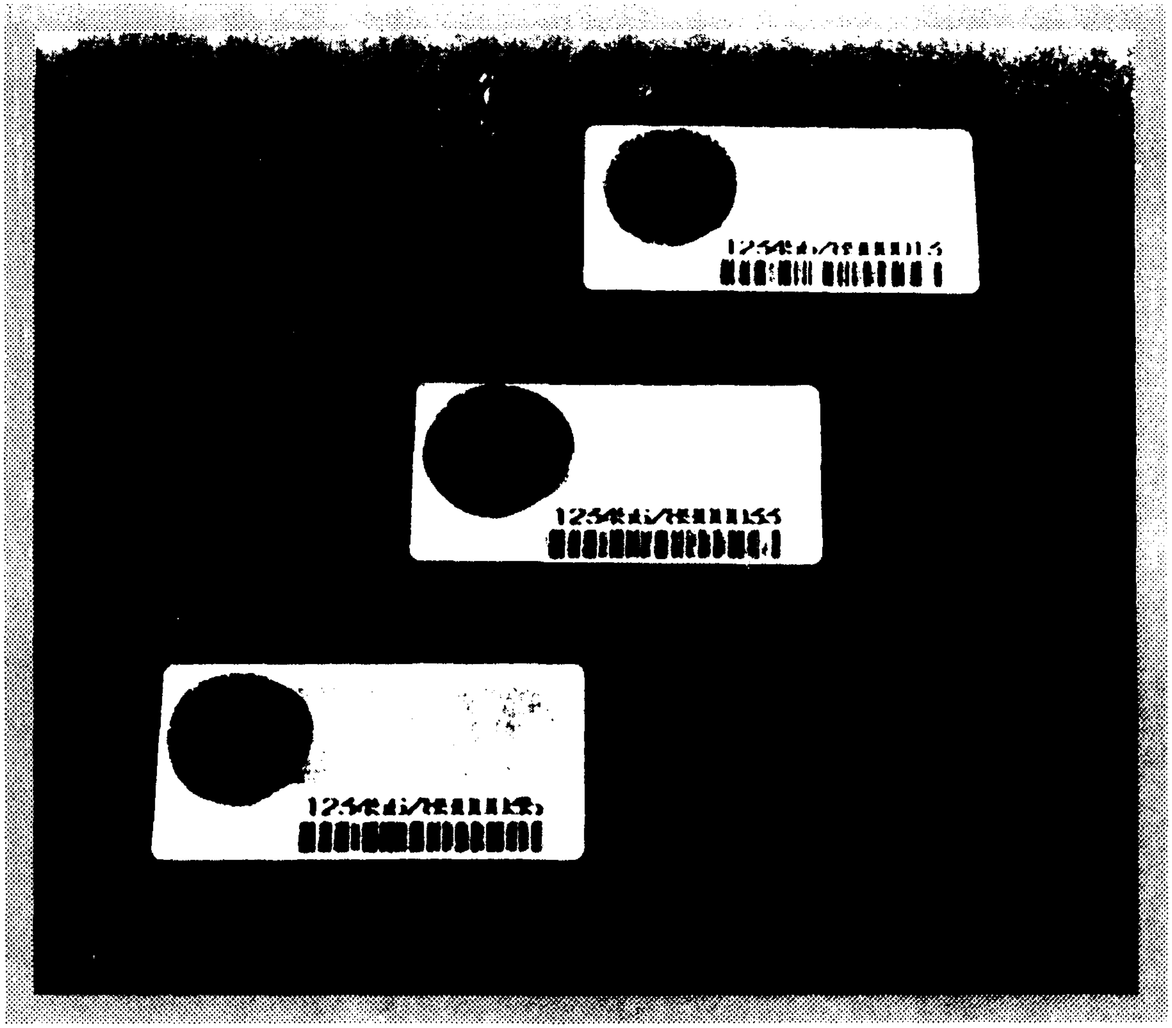
Provide unique, high security identification for any treaty limited item (TLI) that can accommodate an adhered tag

Status:

Red teamed by LLNL

IOT&E completed

Tamper Tape + RPT



Current prototype design of PNL's Tamper Tape + RPT

Tamper Tape + RPT

Under development by Pacific Northwest Laboratories

Security principle:

The RPT spot provides unique identification to prevent counterfeiting. The special tamper tape design assembles adhesives, frangible film, and print layers to dramatically reveal any attempt to transfer the seal.

Potential applications:

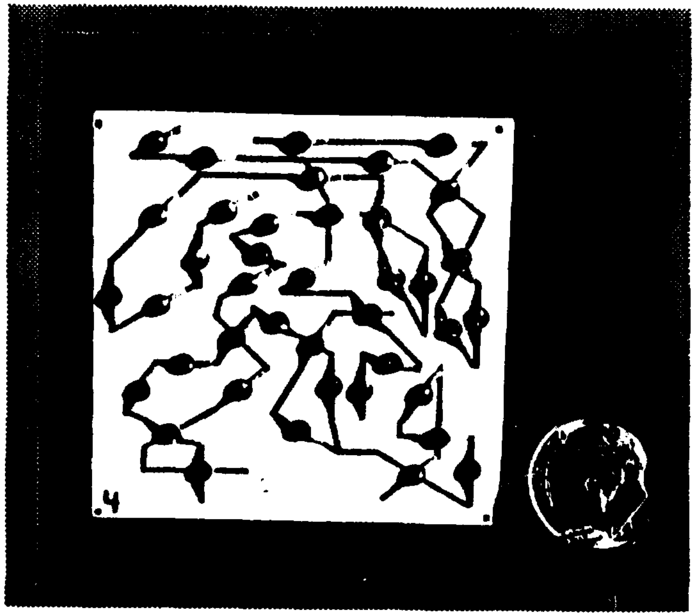
As a short duration tag and/or seal where direct application is permitted for mid to low value items

Status:

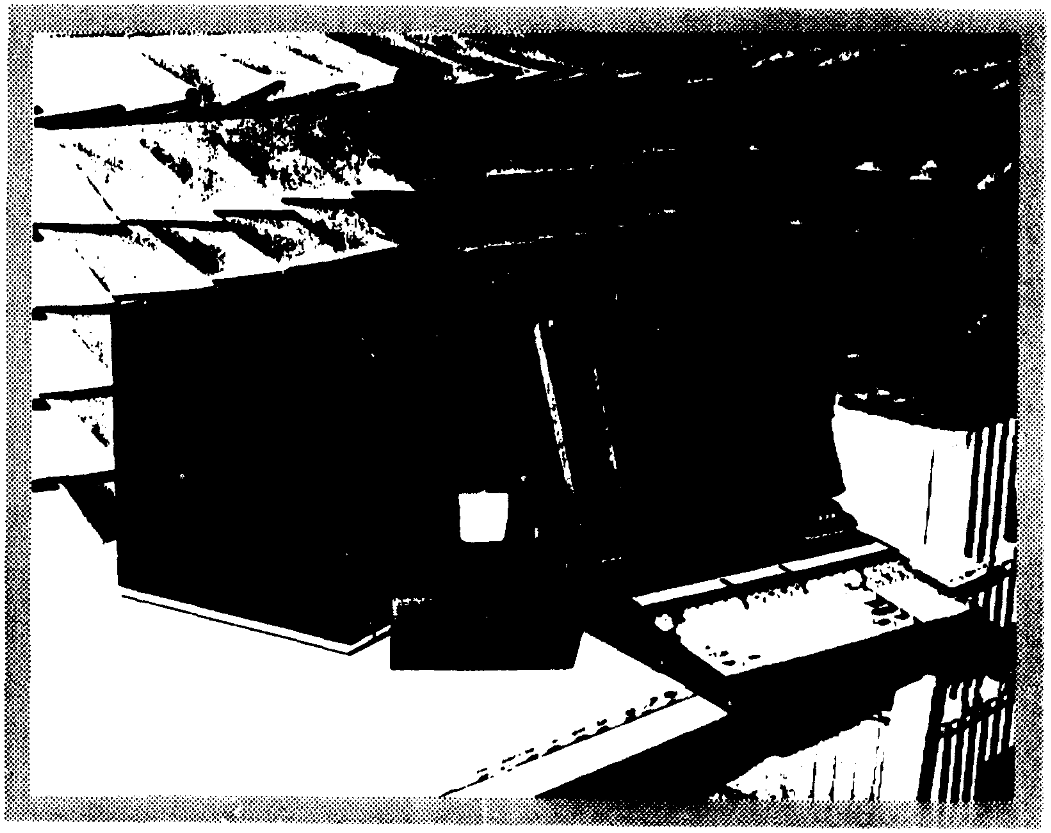
Under development

Joint effort between PNL and a commercial vendor proprietary technology

Nonlinear Junction (NLJ)



Prototype NLJ tag



Nonlinear Junction reading system

Nonlinear Junction (NLJ)

Developed by Idaho National Engineering Laboratory/EG&G Santa Barbara

Security principle:

Nonlinear electronic devices reradiate a complex unique electromagnetic spectrum when illuminated by a low power, swept frequency, CW microwave source.

Potential applications:

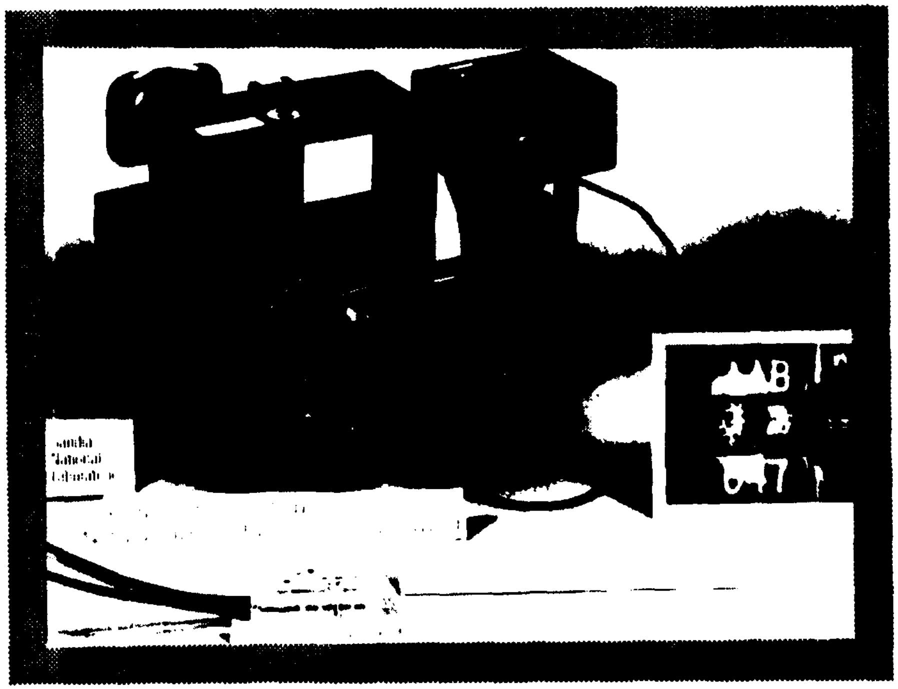
Provide unique identification for items that can accommodate an adhered tag in an environment where low power (~5W) microwave sources are permitted and short range (~1 meter) read distance is desired

Status:

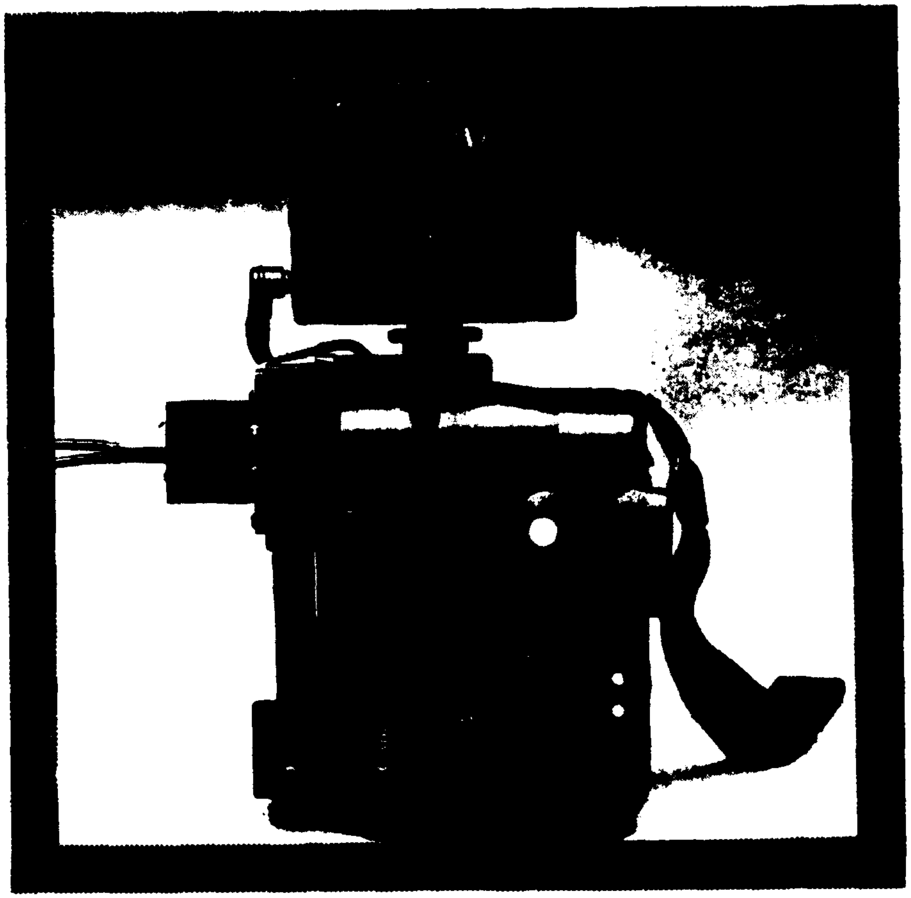
Laboratory prototype developed and tested

Analysis of tag design alternatives in process

Cobra II Seal



SNL's Cobra Seal Polaroid Verifier



Aquila's Cobra II Camera

Cobra II Seal

Developed by Sandia National Laboratories and manufactured by Aquila Technologies Group, Inc.

Security principle:

Both ends of a multiple strand, loosely bundled, plastic fiber optic cable loop are sealed in a clear plastic block. A random number of plastic fibers are cut by a serrated blade creating a unique pattern of light transmission. Both ends of the loop are brightly illuminated and a photograph records the transmission pattern as the signature.

Applications:

Currently being used by OSIA and IAEA to seal inspection equipment containers.

Status:

Seals and recording camera systems are commercially available

VACOSS-S

VACOSS-S seal and palm top reader

VACOSS-S

Developed by Forschungszentrum Julich GmbH. and licensed for production to Aquila Technologies Group, Inc.

Security principle:

A coded light pulse is sent through a single strand, glass, fiber optic cable loop 4 or 8 times a second. Any interruption or significant intensity decrease in the expected signal causes a "tamper event" to be recorded in the seal's digital memory.

Potential applications:

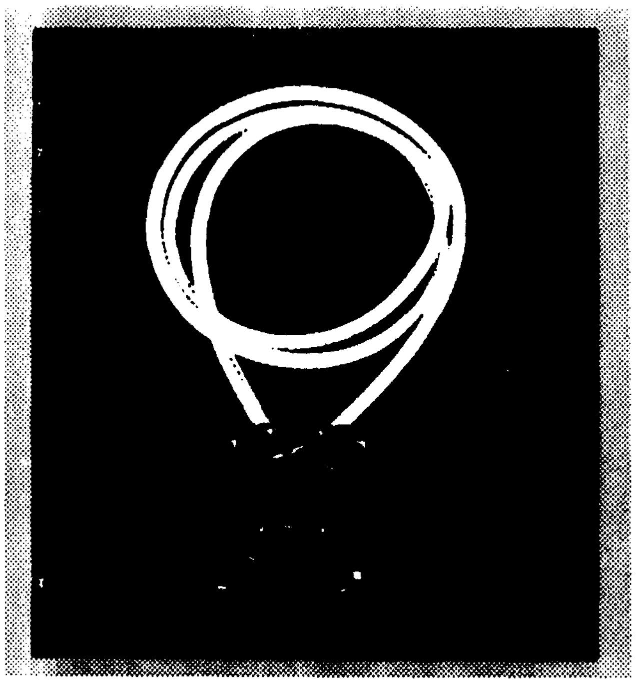
As a reusable high security seal

Status:

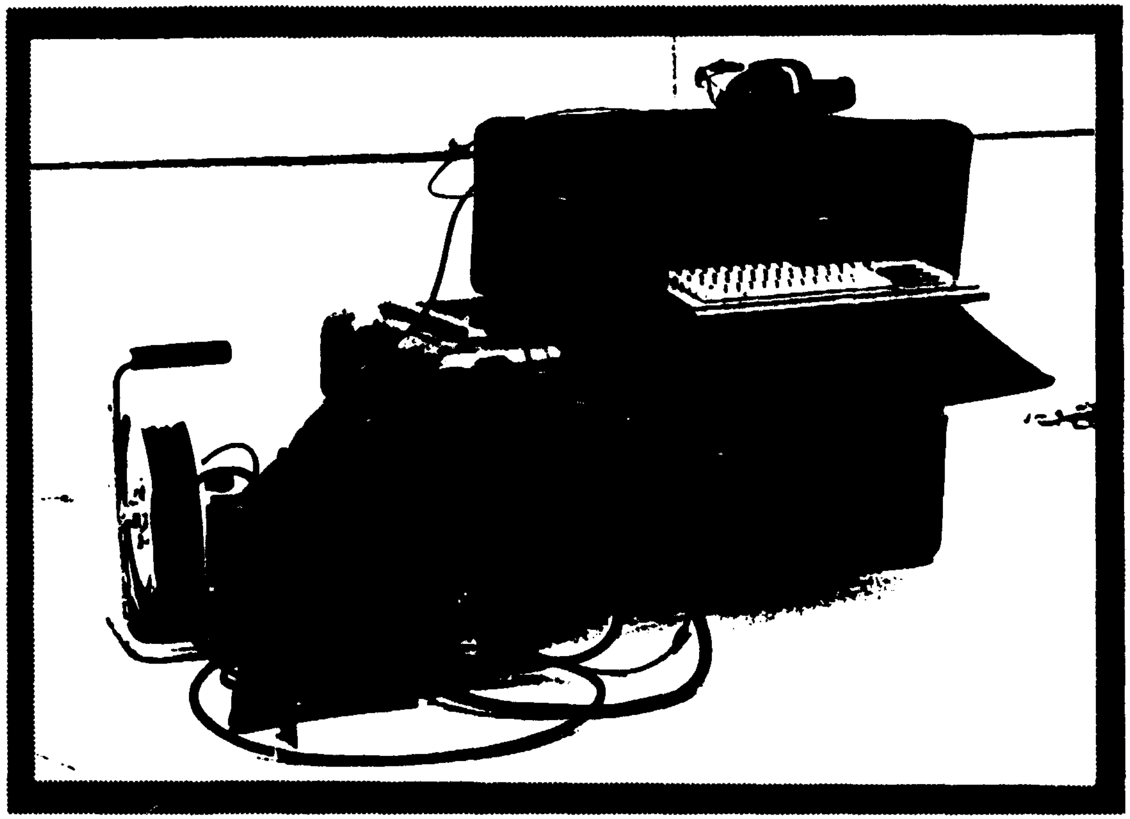
DNA has begun functional and environmental testing of initial production units

JAYCOR is performing an adversarial analysis of VACOSS-S for DNA

Secure Loop Inspectable Tag/Seal (SLITS) and Universal Reader



SLITS



Universal Reader

SLITS and Universal Reader

Developed by BDM International, Inc., under DNA001-89-C-0189

Security principle:

Embedded RPT signature provides unique identification. The loop material and joint block are visually and tactilely inspected for evidence of tampering. The loop materials are very difficult or impossible to cut and splice without detection.

Potential applications:

A high security tag/seal where passive loop configurations are preferred and inspection access to the entire loop is permitted

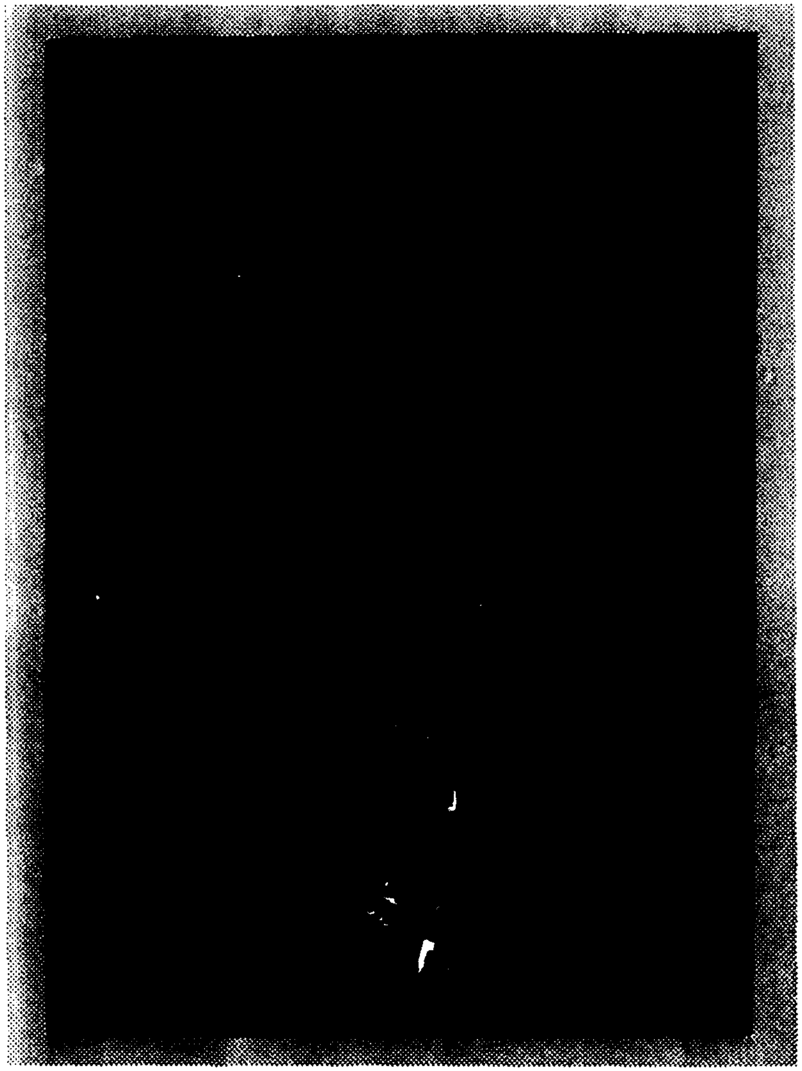
Status:

Red Team activities in progress by INEL

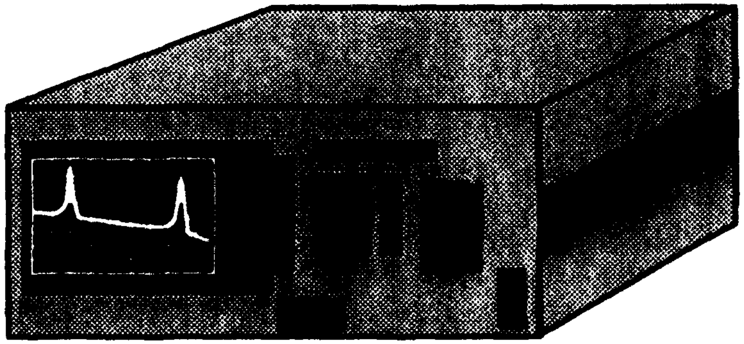
IOT&E completed and data analysis in progress

Environmental testing in progress

Passive Tamper Indicating Loop Seal (PTILS)



Laboratory prototype PTILS



Opto-Electronics' OFM20 Optical time domain reflectometer (OTDR)

Passive Tamper Indicating Loop Seal (PTILS)

Developed by BDM International, Inc., under DNA001-89-C-0189

Security principle:

RPT signature embedded in the joint block provides unique identification. Plastic fiber optic loop material cannot be cut and spliced without detection by a sensitive optical time domain reflectometer such as Opto-Electronics' OFM20.

Potential applications:

High security seal where passive loop configurations are preferred (for minimal intrusiveness or for environmental robustness)

When inspection access to the entire loop may not be permitted

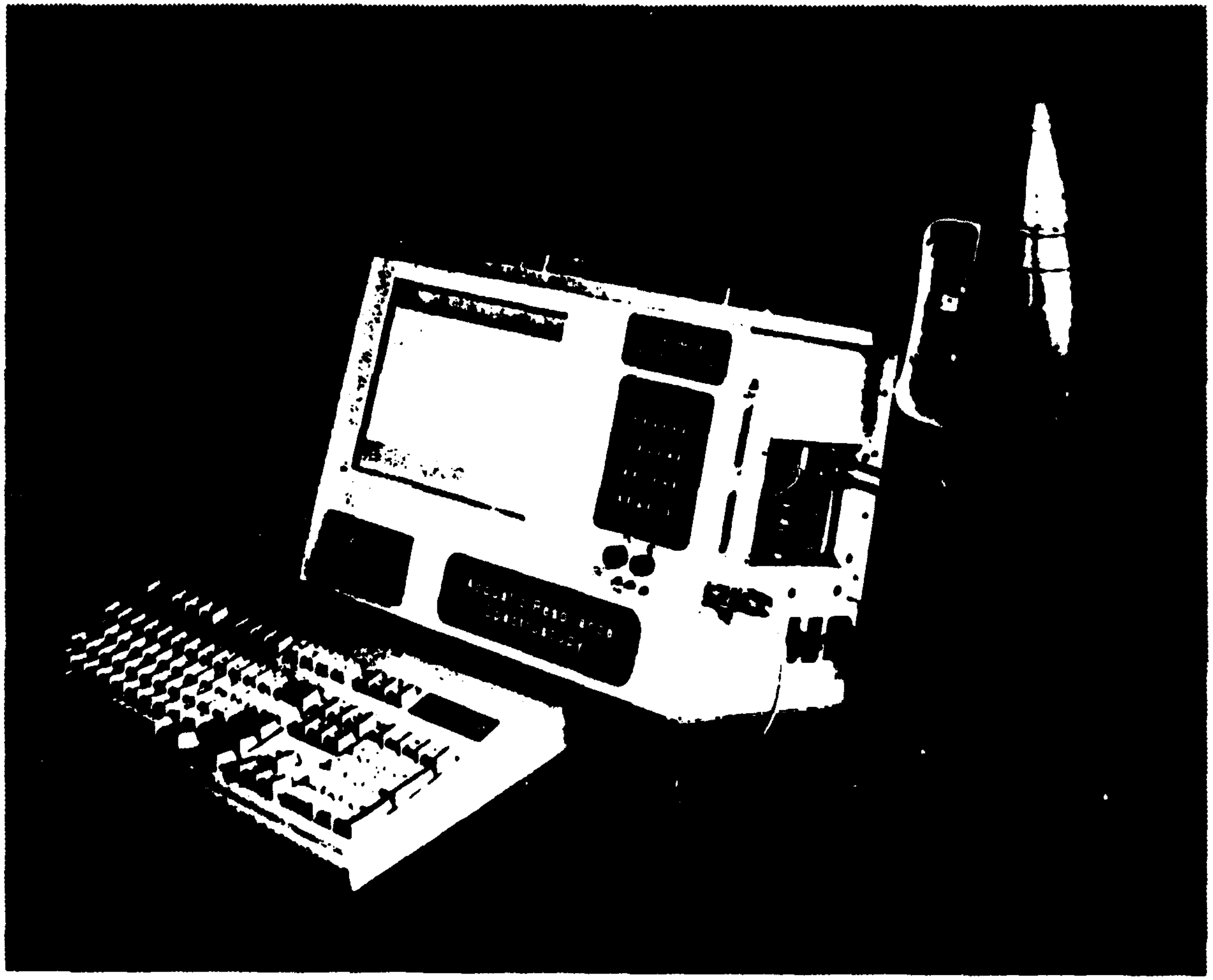
For objective, in-field tamper detection

Status:

Proof-of-principle has been demonstrated

Approximately 6 months required to develop and test industrial prototype

Acoustic Resonance Spectroscopy (ARS)



The Acoustic Resonance Spectroscopy system

Acoustic Resonance Spectroscopy (ARS)

Developed by Los Alamos National Laboratory

Security principle:

Acoustically excited structures produce a characteristic resonance spectrum

Potential applications:

Differentiate CW and conventional artillery rounds

Uniquely identify ICBM stages or complete missile systems

Differentiate nuclear from conventional cruise missiles

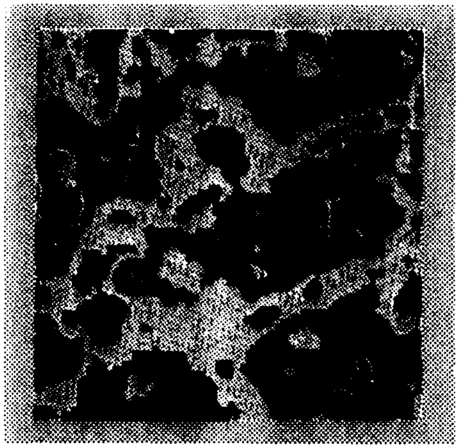
Status:

Prototype system was used by the UN Special Commission in Iraq to identify conventional high explosive versus CW munitions.

Field measurements of MM III are planned to determine if individual ICBMs can be uniquely identified.

Field measurements are planned to determine whether ARS can be used to differentiate nuclear from conventional cruise missiles while still in their transport containers.

Ultrasonic Intrinsic Tag (UIT)



Reference image

Test image

UIT system during developmental testing

Ultrasonic Intrinsic Tag (UIT)

Developed by Pacific Northwest Laboratories

Security principle:

Uses a low energy, scanned, acoustic transducer system to create a unique signature from the three-dimensional structural features of a TLI's composite surface material

Potential applications:

Provide unique intrinsic identification for TLIs that have composite surface materials

Status:

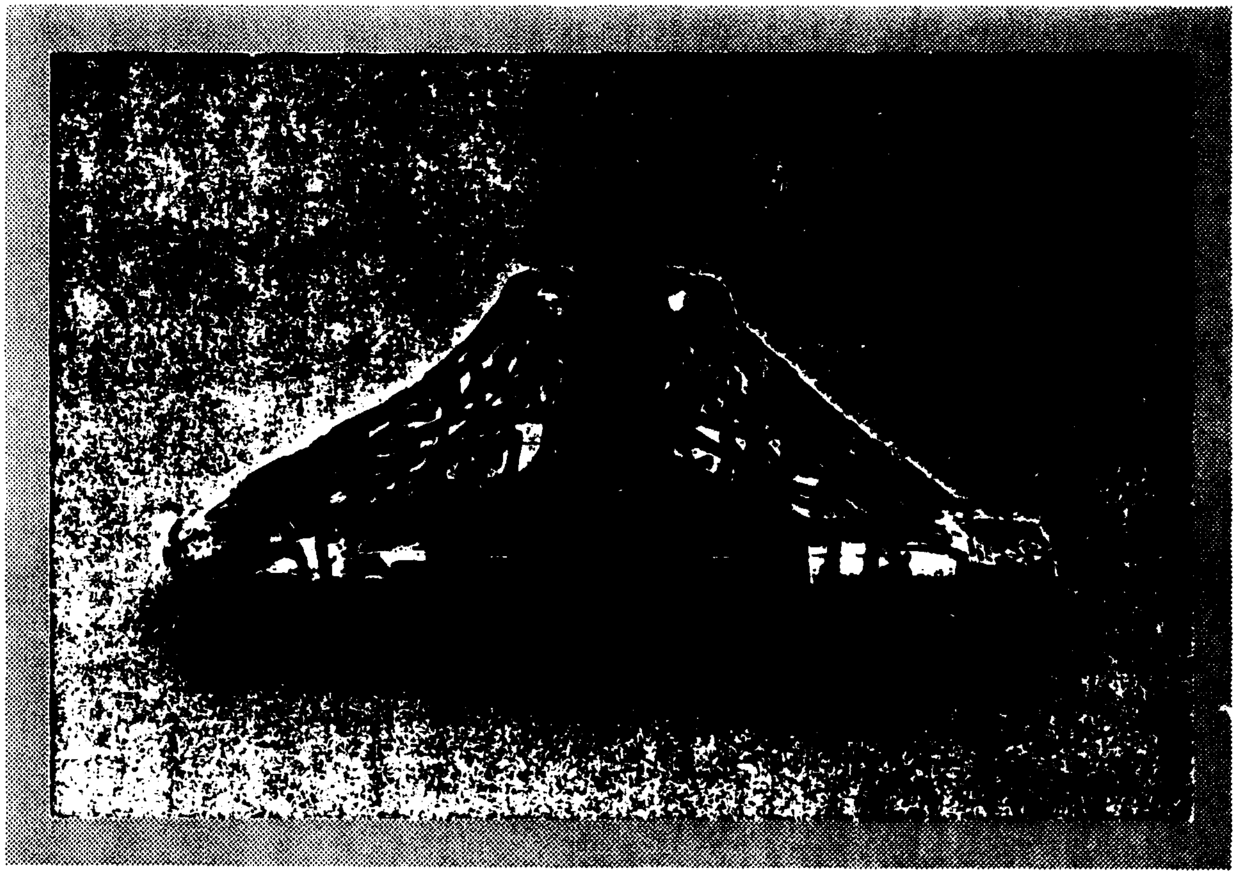
Red Teamed by Argonne National Laboratory

Extensive developmental testing performed by DNA

Prototype composite measurement system archived

System for measuring metals under development

Shrink Wrap



Shrink Wrap applied to a gate valve

Shrink Wrap

Concept originated by Brookhaven National Laboratory and developed by Sandia National Laboratories

Security principle:

A thin, transparent film, bearing printed, periodic, opaque images on one surface, is wrapped around an object several times. The film is heated to cause it to shrink and tightly capture the object to be sealed. The overlapping printed film layers form a complex, random image that is recorded with Polaroid pictures taken from several angles. Attempts to tamper with the seal cause detectable changes in the recorded image patterns.

Potential applications:

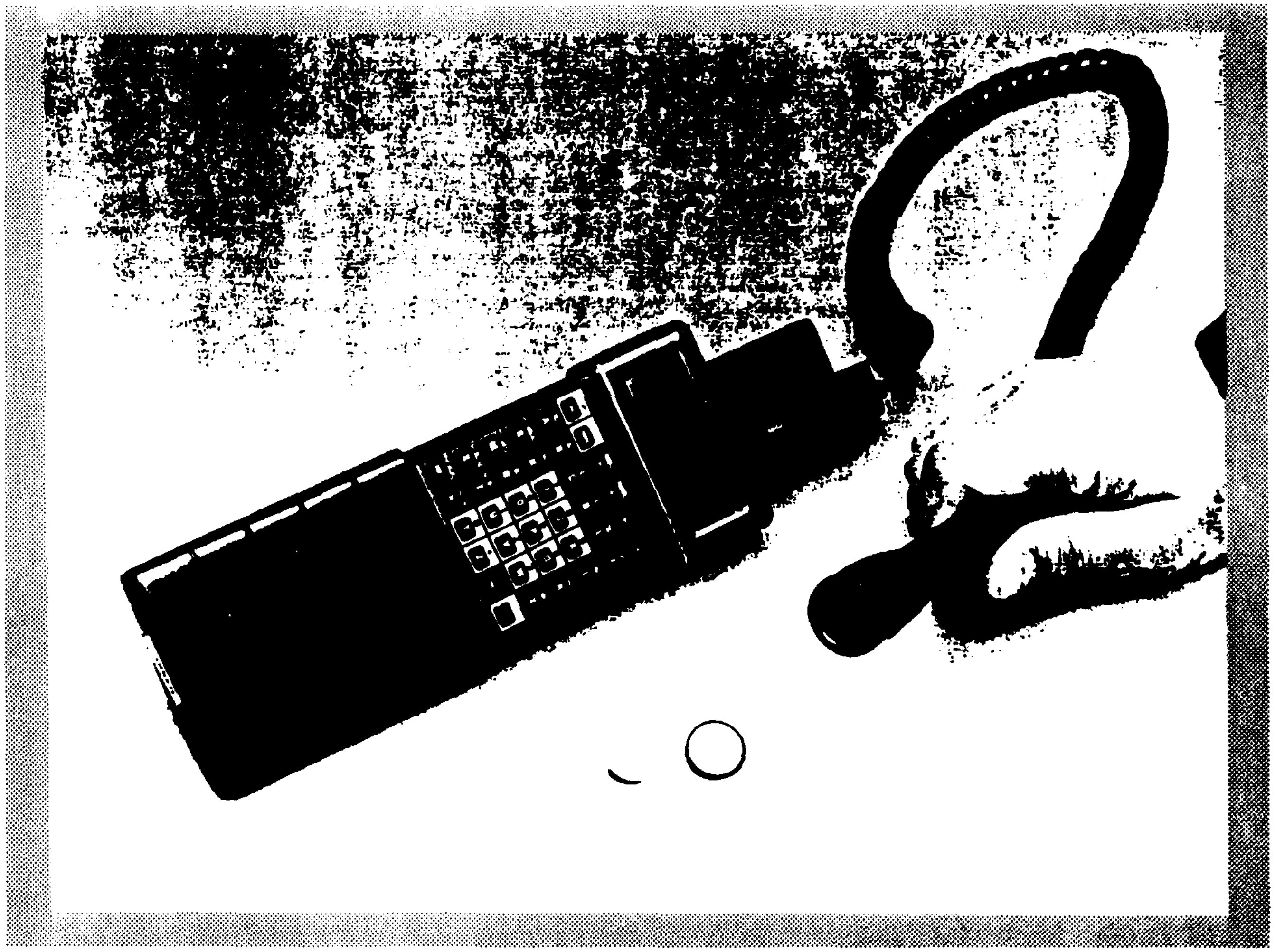
Provide a high security seal for control devices (i.e., gate valves), open flanges, inspection equipment remaining in the inspected country, etc.

Status:

Red Team is being performed by LLNL

CW materials compatibility testing is being performed by CRDEC

Electronic Identification Device (EID)



LLNL's prototype EID system

Electronic Identification Device (EID)

EID "cornerstone" concept developed by Lawrence Livermore National Laboratory

Security principle:

Encrypted identification and digital announcement of tampering based on the status of tamper sensors

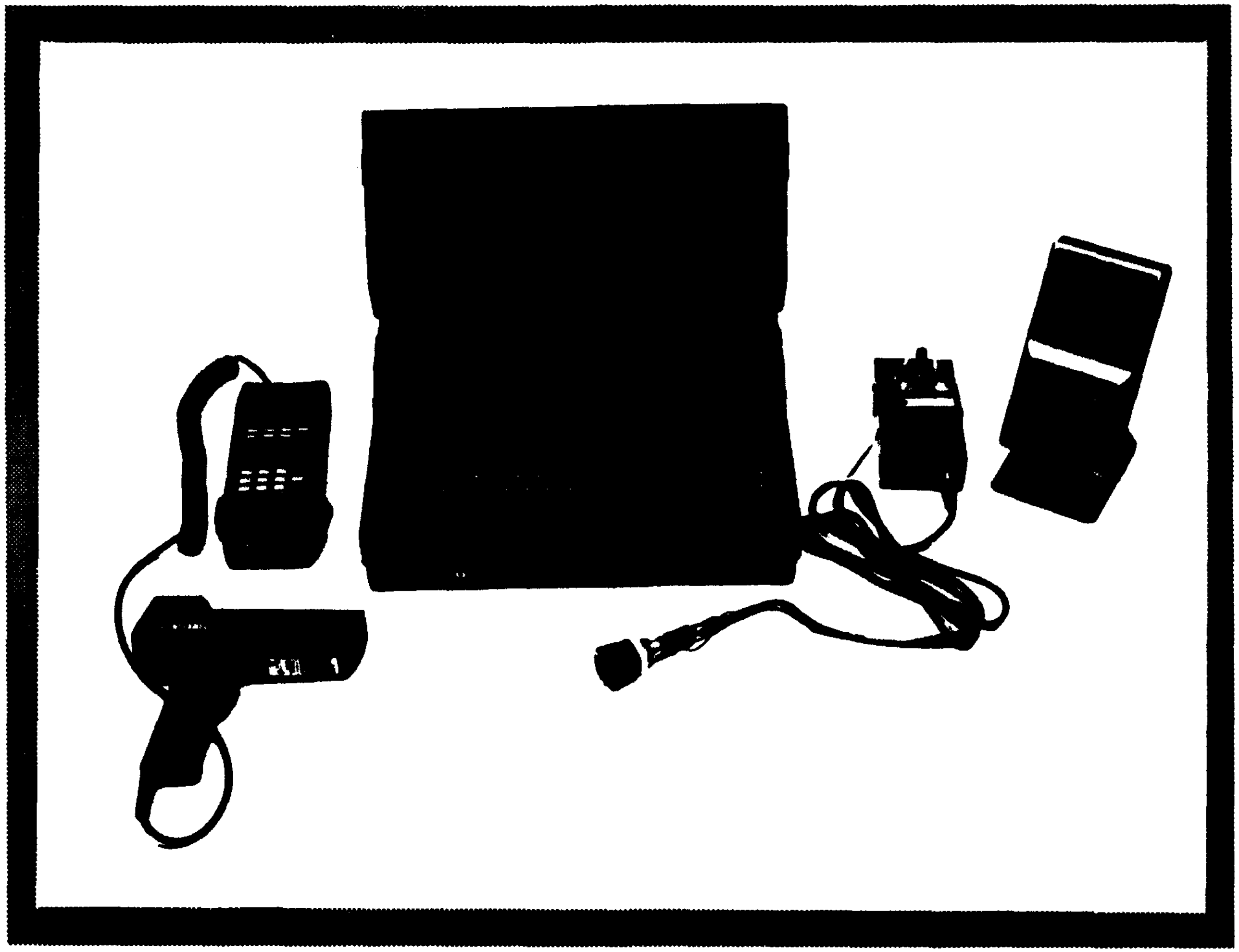
Potential applications:

A tag/seal with many input/output configurations to accommodate verification requirements (especially where rapid read and/or remote query are desired)

Status:

LLNL awaiting production of microchip that combines encryption and tamper detection

Microvideography



Microvideography system incorporating commercial bar code technology

Microvideography

Developed by Pacific Northwest Laboratories

Security principle:

High magnification, video camera inspection of commercial bar codes reveals unique characteristics of individual tags

Potential applications:

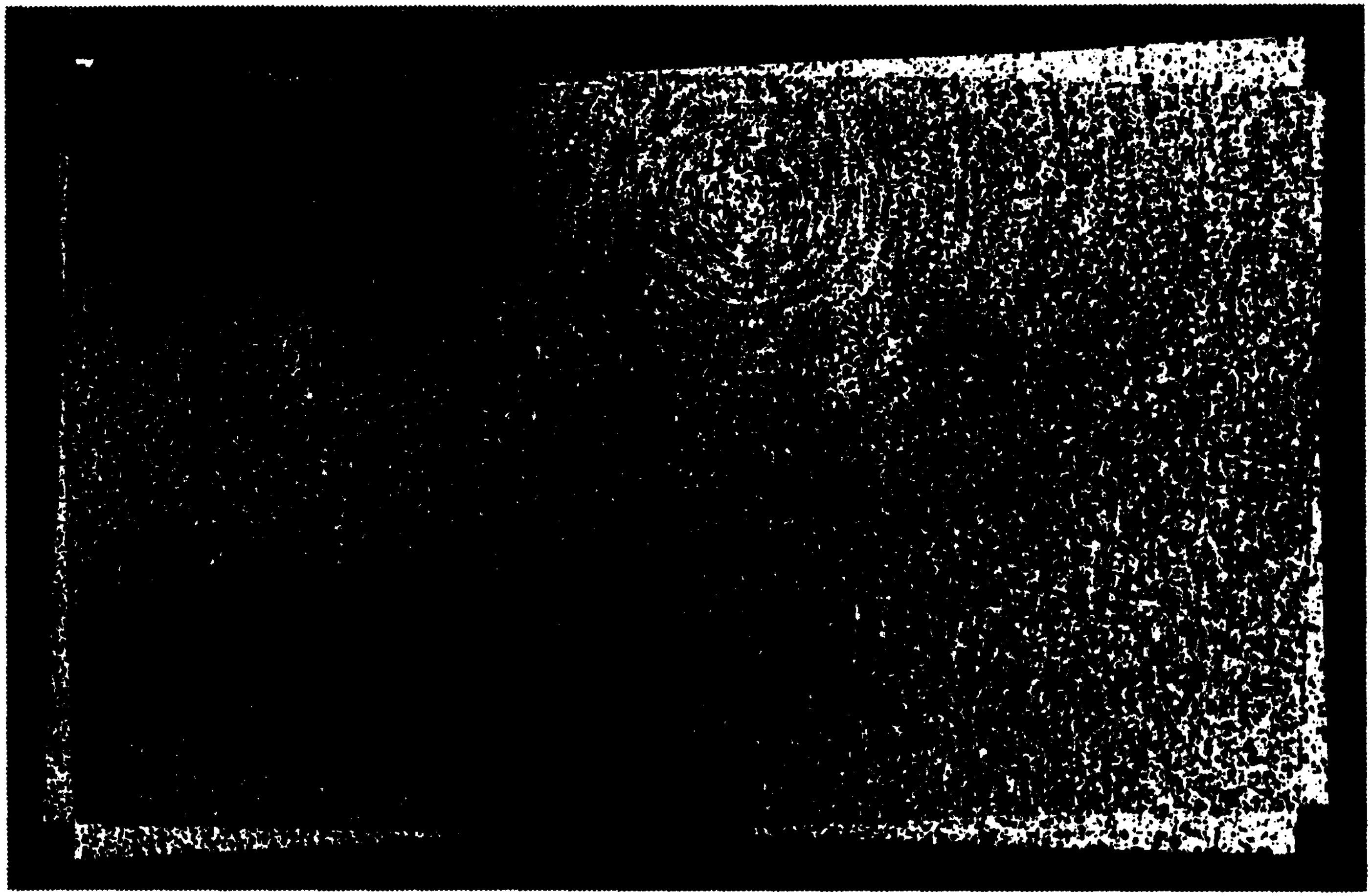
Supplement inventory control of large numbers of accountable items by periodically examining small quantities of bar code tags under magnification to confirm that they are the same tags that were originally applied

Status:

Prototype system developed

Functional assessment performed by DNA

Optical Encoding (MIKOS)



MIKOS tag and positive image overlay showing "flash correlation artifact"

Optical Encoding (MIKOS)

Developed by MIKOS Corporation (IDR)

Security principle:

The MIKOS tag is a random, three-dimensional mosaic pattern adhered to the surface of a TLI. A positive, full scale, two-dimensional image of the tag is produced on transparent film. A Moire-like pattern, called a "flash correlation artifact," is produced when the correct positive image is superimposed on the original tag.

Potential applications:

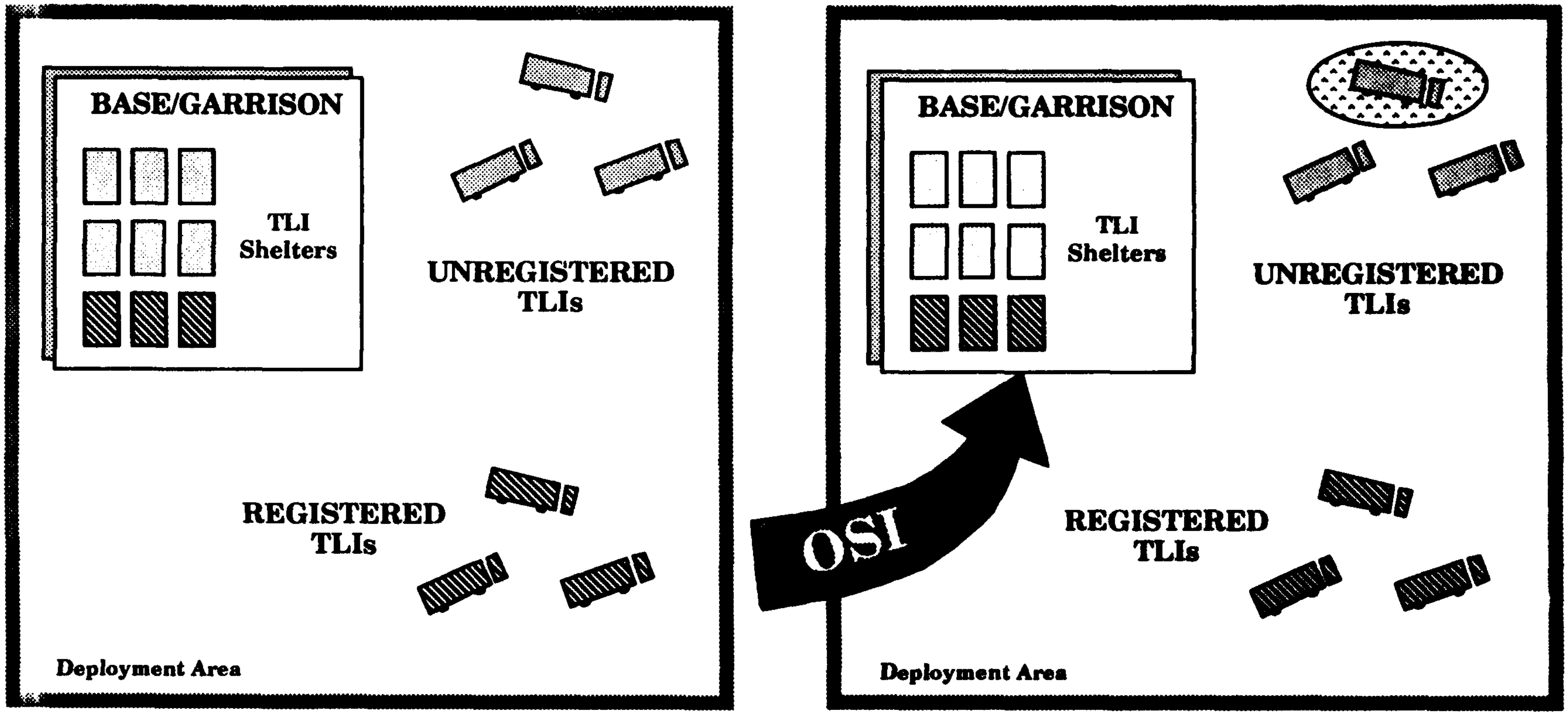
To provide unique identification for TLIs without the need for special reader equipment on verification inspections

Status:

Preliminary concept assessment performed by DNA

The MIKOS technique is being applied to the Brooks Seal

Secure Registration System



6 legal TLIs in shelters

(Require 6 encrypted reports)

3 encrypted reports left for DA

Using only 3 encrypted reports for shelters increases vulnerability to OSI

OSI team counts 6 occupied shelters

(Requires SRS reports for the 6)

3 of 6 TLIs in DA have no reports

(Any one is vulnerable)

If 6 reports had been used for DA, 3 TLIs in shelters have no reports

Secure Registration System

Originated by the JASONS and further developed by NSA and PSR Services, Inc.

Security principle:

Originally conceived for use with mobile TLIs. Each party must periodically report the locations of its mobile TLIs. The coordinates are encrypted and transmitted to the inspecting party. When challenged, the inspected party provides clear text coordinates for the TLI in question. These coordinates are processed, using the same encryption methods, to produce the previously reported encrypted message.

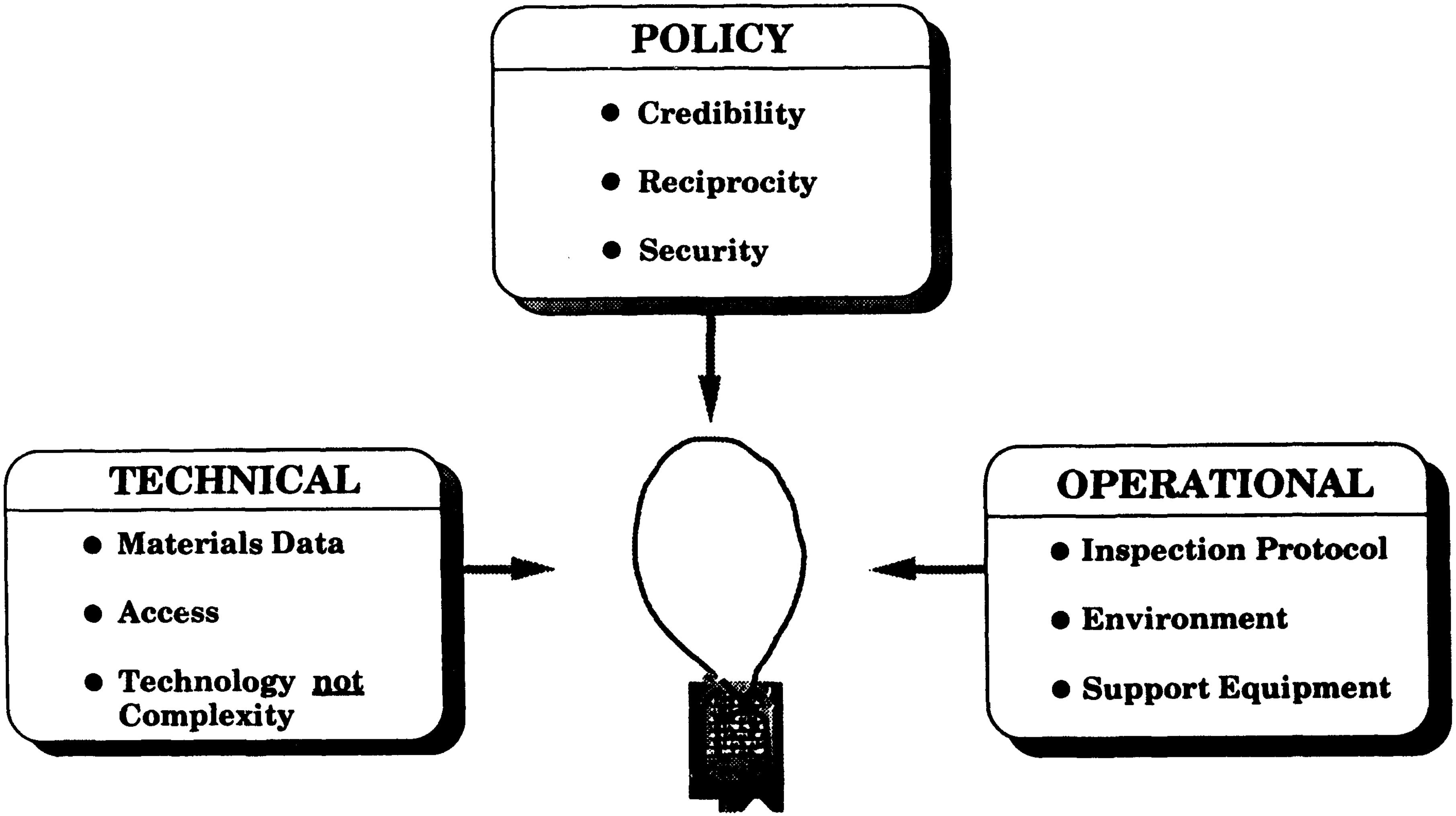
Potential applications:

SRS provides a high security method of ensuring that mobile TLIs are being accurately reported without disclosing targeting data.

Status:

Available for use

Development Challenges



The Potential Role of Aerial Monitoring in Verifying a Ban on Chemical Weapons

A. Fitch
Global Outlook

Prepared for:
Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

The Potential Role of Aerial Monitoring in Verifying a Ban on Chemical Weapons

Arthur H. Fitch
Senior Science Associate
Global Outlook
405 Lytton Ave
Palo Alto, CA 94301
(415) 321-3828
FAX 321- 0805

1.0 Introduction

The problems of verification of the Chemical Weapons Convention (CWC) are unique and difficult. The lessons learned in Iraq and elsewhere demonstrate a need for a strong regime of verification. It is a central point of this paper that verification of compliance with the CWC could be greatly strengthened by supplementing on-site inspection by aerial monitoring.

As of this writing it appears that a CWC will be signed in the very near future, possibly prior to publication of these proceedings. The most recent version of the rolling text indicates that consideration of aerial monitoring has been dropped and this is borne out in the recent German draft of the proposed convention. Nevertheless, the advantages of aerial monitoring are many, and its value in strengthening the CWC is persuasive. It is conceivable that at some future time aerial monitoring will be reconsidered as a means of verification and incorporated into the CWC.

We will look at three aspects of aerial monitoring. First, we will list the overall benefits which it would provide to the CWC. Second, we will examine the specific provisions of the CWC requiring verification to which aerial inspection would be appropriate. And finally, we will review some of the most effective remote sensing and air sampling technology.

2.0 Benefits of Aerial Monitoring.

- Aerial monitoring would serve as a deterrent to clandestine production of chemical agents, both by raising the cost of cheating, and by increasing the probability of detection.

- High-resolution photographs, taken from the air prior to OSI, could help to familiarize inspectors with plant layout, permitting more effective use of their time on the ground.

- Aircraft can be brought on site more quickly than ground inspection teams, especially if the inspection site is in a remote area. Even if direct overflights are not permitted during perimeter negotiations, remote chemical sensing, stand-off photography and downwind air sniffing could be employed early in the game, before concentrations of telltale chemicals had dropped to undetectable levels.

- Aerial monitoring has the capability, not shared with OSI, to uncover clandestine sites or to check out facilities in remote locations, possibly cueing OSI.

- An overflight agreement, as in the Open Skies Treaty, would serve as a confidence-building measure.

3.0 The Chemical Weapons Convention

In its present form, the Convention has two objectives. First, states possessing chemical weapons must destroy their CW stocks and production facilities. Second, the industrial capability of all signatory states to produce CW must be maintained at a zero level. In other words, possessor states must not resume production after destruction of their facilities, and non-possessor states must not originate production. Both of these restrictions require verification. The destruction of stocks and facilities would take place over a fixed period of time, while verification of non-production would continue into the foreseeable future. Table 1.0 lists specific provisions of the CWC requiring verification.

Table 1.0
<u>CWC Provisions Requiring Verification</u>

1. Declared chemical agents and precursor stocks.

2. Movement of stocks to demilitarization sites

3. Demilitarization of stocks (destruction)

4. Transport of permitted CW agents

5. Chemical training exercises for defensive purposes

6. Declared agent production facilities

7. Agent facilities destruction

8. Single permitted CW production facility

9. Nonpermitted use of CW (e. g. warfare)

10. Commercial chemical production

The first eight provisions relate to facilities declared by the signatories or activities permitted by the Convention. The last two items deal with undeclared facilities or non-permitted activities. With one possible exception, OSI would be applicable to all of the provisions. That exception could occur in connection with Provision 9, nonpermitted use, where inspection teams might be denied access because of continuing hostilities, or because of potential chemical hazard in the vicinity of alleged use.

Verification tasks associated with the first five provisions involving declaration, transport and destruction of chemical stocks, and defensive exercises, would be best accomplished by ground inspection. The verification tasks associated with these provisions would not impose a heavy load on the CWC Inspectorate. The destruction sites are few in number and the destruction would occupy a limited time period, whereas other provisions, as we have noted, require verification as long as the CWC remains in force.

Provisions 6 and 7 require the declaration, shutdown, and eventual destruction of agent production facilities. Once shut down, the non-operational status could be continually monitored from the air up to, and throughout the destruction phase. Infrared technology provides a very effective means of determining the operational status of a facility. Fig 1 shows infrared imagery of a Silicon Valley plant taken from a small Cessna aircraft at an altitude of 1000 ft. at 3:00 a.m. The imager was a single-channel imager operating in the thermal infrared wavelength range 8-14 μm. Here different levels of infrared intensity are imaged at different grey-scale levels. From images such as this it is possible to detect operating or recently-operated vehicles, underground heating pipes, warm liquid or vapor emissions, and many other signatures of an operational plant. Fig. 2 shows the same plant, but the infrared intensities have been highlighted by what is called pseudo-color enhancement. From images such as these there could be little doubt as to the operational status of a facility.

Referring again to Table 1.0 we note Provision 8, dealing with the single permitted CW production facility. The CWC permits a single facility, with production limited to a small amount per year for defensive and medical research. Because of the very limited production, the facility would be non-operational for most of the year, and the remarks just made with respect to verifying operational status by infrared would apply here as well. A number of other verification techniques, both airborne and ground-based, could be brought to bear on the single permitted facility. The sites might also serve as a convenient means of calibrating both airborne and ground sensors. Here then, are three provisions, for which verification of compliance with the Convention consists primarily in verifying operational status, and the verification can be accomplished with a high degree of confidence from the air.

Provision 9 deals with nonpermitted use. The U.S. Army has supported a considerable amount of development of sensitive and ruggedized instruments for detecting chemical agents in the field. Field tests both in this country and abroad have demonstrated successful detection of chemical agents (or simulants) both on the ground and from the air. A series of tests was conducted by the Finnish Government in 1986 using high volume air samplers both on the ground and in aircraft. Simulants released from low flying aircraft were detected over 150 km from the release site with detection sensitivities in the nanogram range. We will have more to say about technologies having such sensitivities.

We finally arrive at Provision 10, the briar patch of verification. It is this provision which will generate the great bulk of work for the CWC Inspectorate. This is true for two reasons. First, as we noted earlier, the verification will not end with the initial phase involving destruction of stocks and declared sites, but will require continuing verification. Second, the task is swollen by the large number of facilities to be inspected, e. g. over 5000 chemical plants in the U. S. alone.

4.0 Simplifing the Verification Process

It has been a matter of concern as to how to limit the number of required inspections in a way that would be consistent with strong verification; how to avoid time-consuming inspections stretching from New Jersey to California and concentrate resources where there is the greatest chance of detecting cheating. One suggestion made at the recent verification conference at Southern Methodist University was to focus particular attention on states that balk at, delay, or refuse inspections.

Aerial monitoring could both strengthen and simplify verification of the CWC. Imagine a CWC aircraft on a routine patrol. From a distance of several kilometers a variety of instruments could be trained on a plant and its effluent and air samples collected downwind. Let us say that the detected chemicals agree with the announced commercial profile for the plant and no trace of CW precursors or degredation products are detected. Coupled with other information obtained through data exchanges plus a strong track record of compliance, an overall benign signature might result in waiver of OSI.

Thus airborne monitoring could act as a filter, thereby lightening the load of the CWC Inspectorate. But in addition to this filtering, airborne monitoring could yield another benefit. By possibly eliminating many inherently intrusive on-site inspections, the CWC is made politically more acceptable. Achieving acceptability of the CWC will require a balance between intrusiveness and the desire to protect sensitive and proprietary information. One concept by which this balance might be achieved is through sensors which are smart, but not too smart, detecting only as much as is needed to verify compliance, but no more. Related to this is the concept of "negative verification", involving a determination that a restricted item is not present, with no determination as to the content of the analyzed sample.

5.0 Air Sampling and Analysis

Some of the most sensitive techniques of analytical chemistry are those in which a separation device is combined with a detector, sometimes referred to as hyphenated techniques. An example is gas chromatography-mass spectroscopy (GC-MS). Some recent development in mass spectroscopy have taken place in the laboratory of Brian Andresen at Lawrence Livermore National Laboratory, where recent emphasis has been on developing small, lightweight GC-MS units having sensitivities exceeding even large laboratory models. Fig. 3 shows one such unit, totally contained in an attache case. Another miniature unit of comparable size and sensitivity is shown in Fig. 4. along with a display of precursor chemicals used in the production of chemical agents. Table 2.0 summarizes the key characteristics of these GC-MS instruments.

Table 2.0
Small GC-MS Characteristics

- Weight < 50 pounds
- Battery operated-min.2 hr operation
- No backing pump required during operation
- Source - Electron Impact
- Mass Range - 45 to 650 amu
- Mass Resolution - $m/\Delta m$ > 1000
- Simple operator interface
- Sensitivity: ng - pg

Fig. 5 gives us a view of what we can expect to see in the field of mass spectroscopy in the very near future. The unit pictured is a miniature mass spectrometer complete with microprocessor chip and magnet (Sm Co or Nd Co). These devices have been demonstrated in the laboratory and within the next few years it is very likely that we will be seeing them in a variety of application, e. g. automobiles.

In the previous section we mentioned the idea of instruments which are smart, but not too smart. In the hands of a trained operator and used at their full sensitivity, the state-of-the-art GC-MS instruments which we have reviewed are capable of detecting more than just the presence of precursors or agents. Practically any chemical wafting around can be identified. In particular, a chemical plant inspection could yield a great deal of information about an industrial process. But GC-MS technology lends itself readily to "blinding" of segments of the mass spectrum, concentrating only on a selection of incriminating chemicals.

In addition to the GC-MS instruments, Dr. Andresen's laboratory at Lawrence Livermore has developed selective sniffer units which could be used in airborne applications. Fig. 6 portrays the concept of an airborne sniffer used in conjunction with a time-of-flight mass spectrometer. The combination would provide a real-time map of concentrations in the vicinity of a plant or battlefield.

6.0. Laser Remote Chemical Sensing and Fourier Transform Infrared (FTIR) Spectroscopy

Remote sensing of chemicals by lasers and FTIR are tools already in use for environmental monitoring and studies of atmospheric chemistry. The general concept of laser remote chemical sensing is illustrated in Fig. 7. The beam from an infrared laser directed at a chemical cloud. Some of the radiation is absorbed and scattered back to the instrument where it is focused on a detector. In the most common technique, known as Differential Absorbtion Lidar (DIAL), two lasers of slightly different wavelengths λ_1 and λ_2 are employed. Typically, radiation at one wavelength corresponds to a strong absorbtion feature of the compound being sought, while the absorbtion at the other wavelength is minimal. A comparison of the detected intensities at the two wavelengths yields a quantitative measurement of concentration. All of the known chemical agents and a number of important precursors and by-products are organo-phosphates. These compounds have infrared absorbtion structure in the wavelength range 8-14 μm, a region coinciding with an atmospheric window and covered by CO_2 lasers. The utility of DIAL systems has been demonstrated at a number of laboratories. Researchers at SRI International have constructed a number of DIAL systems and have operated them from aircraft.

Fourier transform spectroscopy has been the subject of a considerable amount of research and development in the past ten years. FTIR units are commercially available from several companies. An instrument for performing FTIR is basically a Michelson interferometer, the layout of which is shown in Fig. 8. In remote sensing the source is not a laboratory source, but emission from a distant chemical cloud. In operation, the movable mirror is translated, and in the process, a time-varying signal, or interferogram, is generated at the detector. The Fourier transform of the interferogram yields the infrared emission spectrum of the distant source. This technique has benefited greatly from advances in computer technology, from opto-mechanical design of the interferometer, and from the so-called Cooley-Tukey algorithm, or fast Fourier transform. Although FTIR differs from DIAL in being completely passive, it does not follow that FTIR is less intrusive. Once the Fourier transform of the interferogram is taken, one has the infrared spectrum of the cloud, whereas the (two-laser) DIAL technique can only focus on a particular absorbtion feature. Recently, however, several researchers, e. g. Robert Kroutil at CRDEC, have demonstrated that by employing digital filtering in the time domain, one can obtain information about spectral features without taking the Fourier transform. Here again, we have the possibility of an instrument which could be smart-but-not-too-smart, detecting the presence (or absence) of incriminating compounds without prying into proprietary processes. Table 3.0 compares some of the pros and cons of FTIR and DIAL. While both FTIR and DIAL have been tested and demonstrated under field conditions both on the ground and from aircraft, neither technology is quite ready for the service which would be required under the CWC. It is estimated that in about 3-5 years, ruggedized off-the-shelf FTIR and DIAL units could be available in sufficient numbers for CWC service.

Table 3.0
FTIR vs DIAL

FTIR	DIAL
IR source not required	2 lasers required
\$20K - \$30K	\$100K - \$300K
IR spectrum obtainable	No spectrum
Passive	Active
Less sens. to interference	More sensitive
Shorter range	Greater range

7.0 Aerial Imaging

OSI comes into play in the course of either a routine or a challenge inspection of a designated site. It has no capability for detecting clandestine operations, whereas an airborne panoramic camera can produce high resolution photographs of a whole country in a few hours. Fig. 9 is a panoramic black and white photo taken from 30,430 ft. with an aerial camera having a focal length of 18 inches. The panoramic camera used for this photograph has an angular coverage of 90 degrees.

Because of the difficulties of verification, it might be possible in some cases to infer the existence of covert production or storage from what might be called secondary characteristics. These indicators could include unusual safety or security measures, e.g. razor wire and armed guards, industrial structures similar to chemical or pesticide plants, chemical storage tanks, heavy-duty provisions for ventilating and air filtering. A key element of photo reconnaissance and analysis relies on the fact that facilities have specific function-related signatures. Utilizing the most recent technology of visible, infrared, and multi-spectral imaging to observe the signatures , a trained photo analyst can frequently determine the function of a facility. Identification of signatures indicative of suspect sites depends strongly on the resolution of the imaging system. Wide-area panchromatic imagery having a resolution of a few meters can be used to cue higher resolution aerial imagery for more detailed analysis. Aerial photography capable of a resolution of less than one inch can be used to identify minute details of plant characteristics and external equipment. Even before inspectors are able to reach an inspection site, stand-off aerial photographs could observe pre-inspection activity at a challenged site, possibly spotting attempts to remove suspect equipment or material.

Fig. 10 shows an example of standoff photography. The photo was taken from an aircraft flying at an altitude of 39,950 ft., at a standoff distance of 25.8 nautical miles from a power plant. About the only items which are identifiable are the white storage tanks. Although the plant is located near a highway, vehicles are not discernable. Fig.11, shows the plant at a magnification of 22X. At this magnification, details such as small storage containers are easily visible, large vehicles are identifiable, and some features of the piping are resolvable. With photographic equipment alone one might easily pick up pre-inspection activity, such as vehicles entering and leaving the plant, movement of storage containers, and cleanup crews on site.

The ER-2 aircraft shown in Fig. 12 is one of two from the NASA Ames Research Center at Moffet Field, California, which are flown on a variety of government, commercial, and academic missions. Fig. 13 is a high resolution aerial photograph of a Chevron refinery at Richmond, California, taken from an altitude of 65,000 ft. from the ER-2 aircraft. The scale of the photo is 1:132,000, and was obtained using Eastman Kodak Panatomic X film. The resolution of the film would permit additional blowups showing even greater detail than the standoff photo shown earlier. Details of the plant layout such as new construction (or destruction), the number and type of vehicles, storage tanks, cooling towers, air filters and security measures would be easily discernible. Even from satellites it is possible to photograph a herd of cows and tell whether they are Guernseys or Holsteins. In Fig. 14 we see the plant imaged with infrared film (wavelengths 500-900 nm), which can be an effective means of detecting camouflage. Fig. 15 is an image of the refinery, obtained with an airborne thematic mapper, a multi-spectral instrument having twelve wavelength bands. Color can be arbitrarily assigned to the various channels to highlight differences. In this image the wavelengths portraying vegetation areas (0.76-9um) are shown in green, the wavelengths which are correlated with soil moisture (1.55-1.75um) are shown in blue, and the thermal infrared (8-14um) is shown in red.

The thematic mapper is frequently used very effectively to document changes in vegetation resulting from various stresses, such as drought or pollution. There has been a relatively large amount of recent research on the vegetation damage resulting from chemical stress, and in some cases the damage becomes apparent from remote observation of the reflection spectra of the vegetation. While the open literature does not indicate any active research dealing with the effect(s) on vegetation resulting from exposure to the organophosphates or related compounds, this appears to be a subject deserving further research.

8.0 Aircraft versus Satellites

It is inevitable that comparisons will be made between airborne sensors and space-based sensors. Stilbrany[1], in a paper presented at the Ottawa Open Skies workshop, drew the comparison. "Space-based sensors and airborne sensors each possess their own advantages and disadvantages which can only be evaluated in terms of cost and mission requirements. Space-based sensors have a wider field of view, are less vulnerable to interference, have greater clandestine value, provide continuous coverage, can provide global coverage, and can transmit their data to a single center for analysis." Except for providing continuous coverage, the above advantages are of secondary importance in verifying compliance with a CW convention. On the other hand, airborne sensors have several advantages over space-based sensors. In particular, airborne systems

1. are much more lenient in terms of size, weight, and power requirements, permitting a greater variety of sensors.
2. can frequently fly under cloud cover that would limit space-based sensors.
3. by operating much closer to their targets, can achieve greater imaging resolution.
4. can employ sensitive air sampling techniques in addition to their capability for remote sensing.
5. make it easier to experiment with new technologies.
6. are easier and less expensive to deploy, test, repair, and upgrade than satellites.

A somewhat different question can be (and has been) asked. Namely, as a cost-saving measure, why not utilize the satellites that are already deployed, rather than launching a new fleet of aircraft for verification? Aside from some of the technical advantages of aircraft over satellites listed above, the data and imagery obtained under the CWC inspectorate must be available to all signatory states. The satellites now in orbit constitute (part of) our national technical means, serving the intelligence community. Except for exceptional circumstances, the data collected from these space-based systems is

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[1] "Open Skies - Technical, Organizational, Operational, Legal, and Political Aspects" Proceedings of Sixth Annual Ottawa Symposium on Arms Control Verification, Ottawa, Canada, Nov. 21-24, 1989. Edited by Michael Slack and Heather Chestnut, Center for International and Strategic Studies, York University, Toronto, Canada. P. 35.

not available to other states because they are, in fact, *national* technical means and will continue to be of value in their own right whatever verification regime is established by the CWC.

9.0 Conclusion

I wish to acknowledge the assistance of an number of agencies and companies which have contributed visual material for this presentation: Lawrence Livermore National Laboratory, NASA Ames Research Center, SRI International, Recon/Optical, Inc., and the 117th Tactical Air Reconnaissance Squadron. Because of the time limitation it has not been possible to cover all of the promising technologies. In the field of analytical chemistry, bio, piezoelectric and fiber optic sensors have demonstrated very high sensitivity. Synthetic aperture radar (SAR), which permits imaging through cloud cover, would be a high-priority choice for an airborne instrument suite (the Open Skies Treaty includes the use of SAR). I have attempted to cover some of the technologies on the cutting edge as well as the older, but highly developed technologies, such as aerial photography. The main point which I wish to make in closing is that the Chemical Weapons Convention deserves strong verification and aerial monitoring could make a significant contribution to that end.

Figure Captions

Fig.1 Thermal infrared image of a Silicon Valley plant taken at 3:00 a. m. from an altitude of 1200 ft. (Courtesy NASA Ames Research Center)

Fig.2 Pseudo-color enhanced thermal infrared image of Silicon Valley plant shown in Fig. 1. (Courtesy NASA Ames Research Center)

Fig.3 Miniature gas chromatograph-mass spectrometer (GC-MS). (Courtesy Lawrence Livermore National Laboratory)

Fig.4 Miniature GC-MS and mass spectrum display. (Courtesy Lawrence Livermore National Laboratory)

Fig.5 Super-miniaturized developmental mass spectrometer. (Courtesy Lawrence Livermore National Laboratory)

Fig.6 Airborne sniffer concept used in conjunction with time-of-flight mass spectrometer (Courtesy Lawrence Livermore National Laboratory)

Fig.7 Differential absorbtion lidar (DIAL) concept.

Fig.8 Michelson interferometer schematic as used in Fourier transform infrared (FTIR) system.

Fig.9 90° panoramic camera photograph taken from 30, 430 ft. (Courtesy 117th Tactical Air Reconnaissance Squadron and CAI, a division of Recon/Optical, Inc.)

Fig.10 Aerial standoff photograph of power plant taken from 39,950 ft. altitude and standoff distance of 25.8 nm. (Courtesy CAI, a division of Recon/Optical, Inc.)

Fig.11 Aerial standoff photograph of power plant shown in Fig.10 at 22X magnification. (Courtesy CAI, a division of Recon/Optical, Inc.)

Fig.12 ER-2 Aircraft. (Courtesy NASA Ames Research Center)

Fig.13 High resolution aerial photograph of a Chevron refinery at Richmond, California, taken from the ER-2 aircraft at an altitude of 65,000 ft. (Courtesy NASA Ames Research Center)

Fig.14 Aerial photograph of refinery shown in Fig. 13, taken with infrared film from 65,000 ft. altitude. (Courtesy NASA Ames Research Center)

Fig.15 Pseudo-color image of refinery shown in Fig. 13, obtained with an airborne thematic mapper, a multi-spectral imager having twelve wavelength bands. Wavelengths showing vegetation areas (0.76- 9.0μm) are in green, those indicating soil moisture (1.55-1.75μm) are blue, and the thermal infrared (8.0-14.0μm) is shown in red. (Courtesy NASA Ames Research Center)

Phase I Development of a CW-Verification Expert System

J. Barden, S. Frankiewicz
Kaman Sciences Corporation

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ABSTRACT

According to the U.S. position on challenge inspection under the Chemical Weapons Convention (CWC), field verification of a CW agent production facility will be performed at a perimeter negotiated between the host state and the challenging inspection team. Because the final perimeter will likely be located away from the production activities of the facility, the inspection team will probably not be able to characterize the true nature of the plant from process samples. Instead, this will have to be done from environmental samples. The critical question is: can the true nature of a suspect facility be determined from environmental samples at the final perimeter--given that prior to inspection production activities will have ceased and the deposited prohibited chemicals will undergo considerable degradation in the environment. Before this question can be answered two important issues need to be resolved: (1) will the presence of unique degradation products of the CWC prohibited chemicals at the perimeter constitute sufficient proof that the facility was using CWC prohibited chemicals and (2) will these degraded chemicals be measurable in the environment. The latter issue is the topic of this paper. Kaman Sciences Corporation has studied several production release mechanisms that may result in significant deposit of CWC prohibited chemicals at the perimeter; they are stack and fugitive emissions, and solid and liquid waste discharges. This paper deals exclusively with stack emissions. Kaman has developed a comprehensive model that predicts: (1) where in the environment samples are expected to contain the highest concentrations of CWC prohibited chemicals from stack emissions, (2) the identity of the predominant unique degradation product(s) in the environment for specific deposited CWC prohibited chemicals and (3) the concentration of all analytes in soil samples. The locations are predicted using EPA's Industrial Source Complex (short term) model in conjunction with site specific meteorology. The predominant chemical(s) remaining after degradation is predicted using a developed chemical degradation model in conjunction with a database of chemical reaction pathways and half-lives of CW-agents in the environment. Predictions of concentrations of the

predominant chemical(s) at the locations are made using a developed vapor-to-soil deposition model along with the chemical degradation model. The comprehensive model and associated database is available for use on a portable or lap-top computer in the field.

Background

The present language of the Chemical Weapons Convention (CWC) treaty implies that a CW inspection team will have to learn the true nature of a challenged production facility from a perimeter whose location will pretty much be decided by the country being challenged. This being the case the perimeter will more than likely be located away from the production activities of the facility. The end result is that on-sight production process samples will not be available for use in determining the true nature of the facility. Instead, only off-sight environmental samples will be available for this purpose. Chemical analysis of these samples for CWC prohibited chemicals released from the facility (or their unique degradation product) may be the principle method available to the inspection team in proving whether or not the facility was recently using CWC prohibited chemicals. The chemical signatures in the environment of the challenged facility will probably not be the prohibited CWC chemicals, but a derivative of these chemicals. There are two reasons for this situation: (1) many of CWC chemicals will react quickly in the environment to form a degradation product(s) and (2) CW-agent production may cease by as much as a week before the inspection is conducted. For example, GB or O-isopropyl methylphosphonofluoridate, a nerve agent prohibited by the CWC treaty, will hydrolyze in about a week to form O-isopropyl methylphosphonic acid (IMPA). Because IMPA can only be formed from GB and because it stays in the environment for a relatively long time (a year or more), the presence of IMPA can only mean that GB was present in the same environment. Other prohibited chemicals, such as VX and the other G-agents, form similar products in the environment that are uniquely related to their parent compounds.

The CWC treaty does not addressed unique degradation products of CWC prohibited chemicals, however, it is suggested that the presence of IMPA be exploited in the inspection process. For the sake of this paper, the referenced analytes in the surface environment will include unique degradation product(s) as well as the CWC prohibited chemical(s).

Problem

Four basic problems need to be addressed concerning sampling the environment. They are:(1) where in the environment will analyte concentrations be the highest, (2) what will be the molecular form of the CWC prohibited chemical, (3) what are the concentration levels of the analytes at the identified locations and (4) can a technique be developed for quickly deriving this information in the field.

Being able to predict the locations of the highest concentrations of analyte(s) in the environment is important because it would (1) assist the inspection team in selecting an optimized perimeter based on concentration profiles during perimeter negotiations and (2) provide sampling locations for the final perimeter.

Prior knowledge on the molecular form of the analyte is important because it would allow the inspection team to better plan the specific protocol and resources for the challenge inspection. Being able to predict the approximate concentration of analytes in the environment is important because it indicates whether or not the analyte is measurable or, for what is measurable, it will assist in estimating the magnitude of analyte preconcentration required.

The above predictions need to be performed in the field because new results will need to be redefined for the final location of the perimeter and because some of the model input data may only be available in the field.

Solution

Kaman has solved the above problems with regard to all three types of environmental release mechanisms (stack emissions, fugitive emissions and effluent discharges), however, this paper deals only with stack emissions.

The solution for identifying the locations of highest concentration of analytes in the environment was achieved through application of gausian dispersion equations in the latest version of the Industrial Source Complex Short Term (ISCST) Model. This model has been extensively field evaluated by EPA, and is used by EPA to assess single and multiple-point sources of stack and fugitive emissions in the U.S. Stack performance and meteorology are the two general categories of data supplied to the model. The duration of production is required and is supplied to the model as starting and ending calendar dates. The model scans up to a year of hourly meteorological data for the period of production. Table 1 displays the model input parameters and associated data. Table 2 displays the text output or results of the model. Figure 1 displays a graphical output demonstrating the use of the model in predicting the location of areas where high concentrations of analytes occur in the surface environment. The data presented in Table 1 and 2, and in Figure 1 pertain to a hypothetical GB production CW-agent facility in Pine Bluff, Arkansas. Hourly meteorological data specific for the Pine Bluff site was used in the model. The text and graphical plot was made under the assumption that the hypothetical Pine Bluff GB plant was producing for a continuous 3-month period (February 1 to April 30, 1991) followed by a 7-day period of no production.

The concentration of analytes in the soil environment was computed for the end of the 7 day no production period (seven days was the estimated time between initial notification of the challenged country and conduction of the inspection).

Table 1 Model Input Parametric Data

PRODUCTION DATA:	
Beginning Date of Production	2/1/91
Ending Date of Production	4/30/91
Period between Cessation of Production and Inspection	7 days
CW-Agent Suspected of Being Produced	GB
STACK DATA:	
CW-Agent Emission Rate	0.190 lbs/hr
Stack Height	100.0 feet
Stack Inside Diameter	1.50 feet
Stack Gas Exit Velocity	038.0 feet/sec
Stack Gas Exit Temperature	124 F°

Table 2 Model Output

DIRECTION (degrees)	DISTANCE (km)	[IMPA] (ppt)
020	0.9	87.9
060	0.3	77.1
070	0.3	86.1
070	0.9	77.7
110	0.4	70.5
120	0.4	72.6
120	0.9	77.3
140	0.3	74.5
150	0.3	76.3
160	0.3	74.6
160	0.9	129.0
170	0.9	77.6
180	0.3	106
180	0.9	109
190	0.3	89.2
190	0.9	136
200	0.9	89.9
210	0.9	87.6
220	0.9	98.5
230	0.9	123
240	0.2	139
240	0.3	71.8
240	0.5	94.5
260	0.3	123

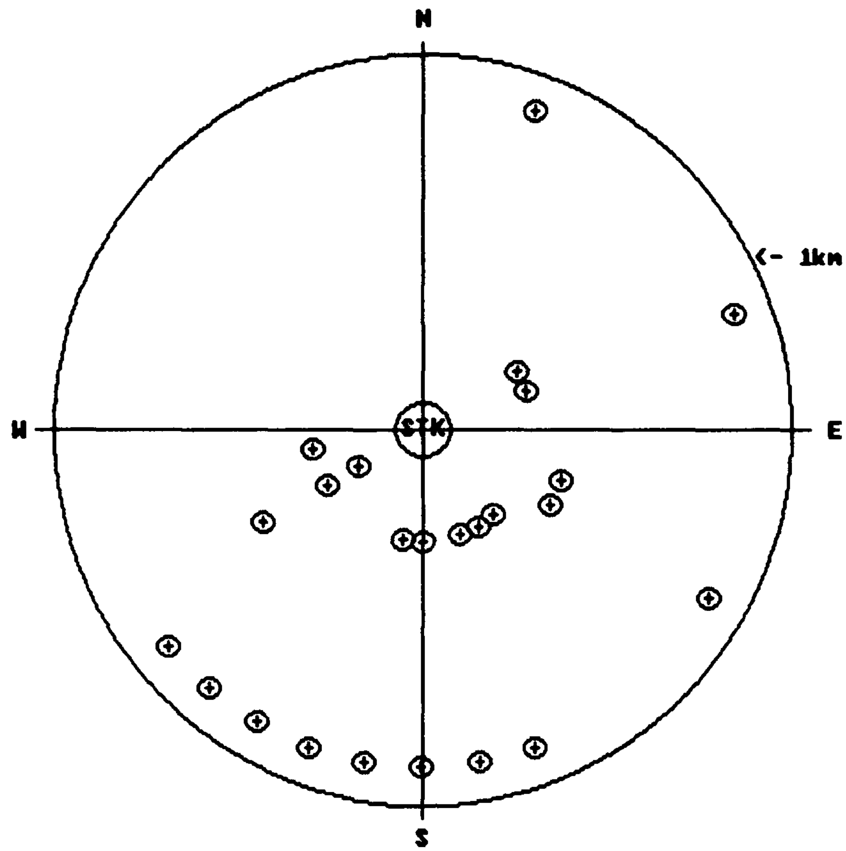

Figure 1 Locations of Highest Concentrations of IMPA in Soil around a Hypothetical GB Production Plant near Pine Bluff, Arkansas after Three Months of Emissions from an Incinerator Stack

The solution for identifying the molecular form and concentrations of the analytes in the surface environment was achieved through a developed deposition and degradation model. The model requires input of the specific CW suspected of being produced. It takes ground level air concentration data from the ISC model for high concentration locations and computes the amount of CWC prohibited chemical deposited on the ground's surface. The computation requires a deposition velocity database for each suspected CWC chemical. Once the amount of the deposited prohibited CWC chemical is computed, the amount of the degradation product(s) and remaining prohibited CWC chemical is also computed.

This portion of the model incorporates vapor-soil flux rate, chemistry pathway and half-life equations to predict the predominant molecular form of the analytes and their concentrations in the soil environment at the locations identified by the ISC model. The model considers half-life of the analytes in the organic, as well as water, phase of the soil environment.

The solution for quickly deriving this information in the field was to tailor the comprehensive model for use in a portable computer. Currently the software operates in either a IBM disk operating system (DOS) or a Sun Operating System (SOS) environment. To compute the highest concentrations locations and the analyte concentrations in the soil environment at these locations requires less than 20 minutes on a 486 portable computer for a 3 month production period. This reasonably short data processing time in a physically small computer makes the comprehensive model amenable for use by inspectors in the field.

The sequence of processing events and inter-relationships of the components regarding the comprehensive model is portrayed in Figure 2.

Importance of Concurrent Meteorology

Figure 3 displays a plot of locations of the locations of the highest IMPA concentrations in soil for the month of January 91. Figure 4 displays the same plot for the same plant and site for the month of the July 1991. The most striking difference between the two months is the computed locations where the highest concentrations occur. The January 1991 plot shows that the majority of the peak concentrations occur 0.9 km from the stack in directions ranging from 20 to 70^{o} relative to the location of the stack. The July 1991 plot on the other hand displays a very different pattern of peak concentrations. Instead of peaking at 0.9 km, the majority of the peaks occurred at 1/9 to 1/3 this distance in directions ranging from 200 to 250^{o} relative to the same location of the stack.

The conclusion of this analysis is that the meteorological data should be concurrent for the model evaluation period of the plant.

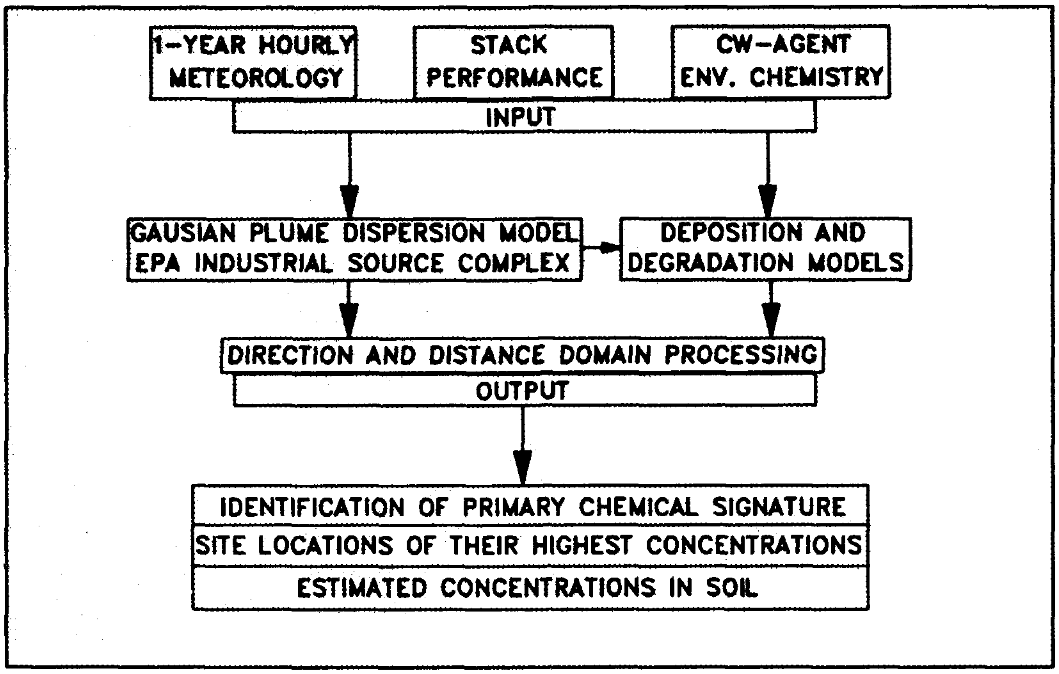

Figure 2 Description of Comprehensive Model and Sequence of Process Events

Future Studies

This work was sponsored by Kaman under an IR&D project, which is still active. The specific CW-agent production facilities that can be modeled include GB, VX and HD. More CW-agent production facilities can be added to the model as environmental chemistry of these agents become known. The current effort of the IR&D study is to determine the reliability of the predicted values by performing an error analysis. Future efforts will involve adding algorithms to the model to handle fugitive emissions and effluent discharges of production facilities. Also a production model is being developed to assist the used in predicting stack performance values from an off-site location.

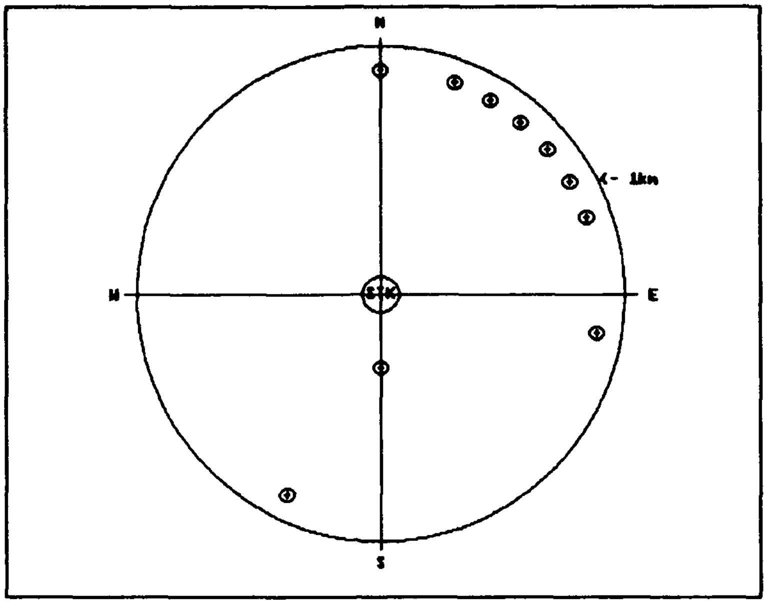

Figure 3 Locations of the Highest Concentrations around the Hypothetical Pine Bluff Site for a One Month Production Period during the month of February 1991

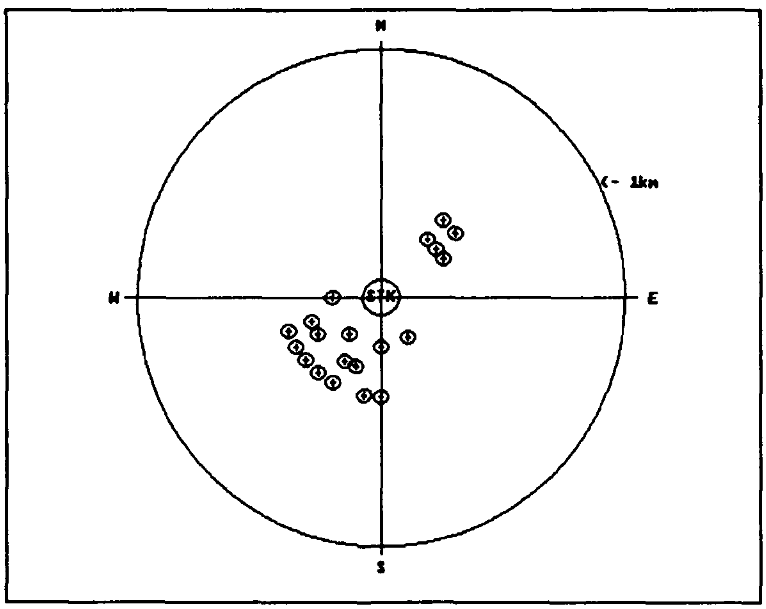

Figure 4 Locations of the Highest Concentrations around the Same Hypothetical Pine Bluff Site for a One Month Production Period during the month of July 1991

Yield Verification of Non-Standard Underground Nuclear Weapons Tests by HYDRO-PLUS

L. Germain, B. Killian
Logicon R&D Associates

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INTRODUCTION

HYDRO-PLUS refers to the methodology used by the United States to verify the yields on non-standard nuclear tests in accordance with the verification protocol of the Threshold Test Ban Treaty (TTBT). This methodology uses technologies and procedures that are used for the hydrodynamic verification of standard tests *plus* additional technologies and procedures that may be required for the verification of non-standard tests.

Non-standard tests are those test that have a configuration other than the standard configuration as defined in the verification protocol of the TTBT. Standard tests are essentially tamped and may have only a small volume (<85 m^3) into which the nuclear explosive is placed. Non-standard tests can have volumes of up to 20,000 m^3 in which the nuclear explosive is placed. A tamped configuration is generally adequate for those nuclear weapons tests that are aimed at obtaining data regarding only the performance of the explosive. However, to obtain data regarding the *effects* of nuclear weapons, much larger volumes are often required. These larger volumes are required in order to encompass the environment in which the nuclear weapons effects occur, e.g., air, different geologic and/or man made materials, etc.

For a nuclear explosive of a given yield, the larger the volume in which the explosive is placed, the lower the pressure available for driving the hydrodynamic motion and stresses in the surrounding rock. The hydrodynamic methodology for standard tests is based on the use of cables to measure time-of-arrival (TOA) of the ground shock along a satellite hole. At stresses below about 100 kbars, this method alone is not sufficient for yield verification.

In addition to TOA cables, the HYDRO-PLUS methodology uses gages that measure particle velocity, stress, and additional higher resolution TOAs. The strengths of the HYDRO-PLUS methodology are:

- In addition to acquiring data at the high level of stresses present in standard tests, it *also* acquires hydrodynamic data that are successfully used for yield verification in much lower stress regimes.
- The different types of data acquired can be used to evaluate the consistency of the data.

These strengths enable the HYDRO-PLUS methodology to provide yield verification at the lower stress regimes present in non-standard tests. If lower thresholds are negotiated in the future for the TTBT, the applicability of the HYDRO-PLUS methodology relative to other yield verification methodologies will increase.

SECTION 1
BACKGROUND

The treaty between the United States of America and the former Union of Soviet Socialist Republics on the Limitation of Underground Nuclear Weapons Tests, also known as the TTBT, was signed in July 1974. It established a nuclear "threshold" by prohibiting tests exceeding a yield of 150 KT. This treaty was not ratified in its original form because of concerns about effective verification of the 150 KT yield limit.[8]

On June 1, 1990, the United States and the Soviet Union signed the verification protocol to the TTBT. The United States Senate gave its advice and consent to ratification of the TTBT and its protocol on September 25, 1990. The Supreme Soviet took comparable action on October 9, 1990. The treaty entered into force on December 11, 1990, through the exchange of the Instruments of Ratification.[8]

The protocol provides the following definitions of terms used in this paper:[1]

- *Standard Configuration* - either the standard vertical configuration or the standard horizontal configuration of a test. For both the vertical and horizontal standard configurations, the protocol sets limits for parameters such as the size of the emplacement hole, location of the explosive canister within the emplacement hole, support of the canister, the thickness and density of the barrier through which pipes and cableways exit the explosive canister (choke section), size and areas of pipes and cableways within the choke section, and bulk density of the stemming material(s) that surround the explosive canister in the emplacement hole.

  The limitations on the size of the explosive canister are

  - Vertical configuration (< 12 m length, < 3 m diameter)
  - Horizontal configuration (< 12 m length, < 3 m by 3 m cross section)

The standard configuration is used primarily by the U.S. Department of Energy (DOE) for conducting diagnostics on the performance of nuclear explosives. Such diagnostics observe the very early time behavior of the nuclear explosive and generally do not require a volume greater than that specified as the limit for the standard configuration.

Non-standard configurations allow for an unstemmed region or cavity surrounding all or part of the nuclear explosive canister. These configurations are of particular interest for studying the effects of nuclear weapons such as radiation, air blast, and ground shock. These configurations are of more interest to the U.S. Department of Defense (DoD) Defense Nuclear Agency (DNA) whose mission is to provide information regarding nuclear weapons effects.

- *Non-standard configuration* - a configuration of a test different from that described for the standard. This definition is quite general, and allows for excavated cavities of arbitrary shape as large as 20,000 m^3. Larger cavities are permitted providing the

Parties agree on verification measures with respect to such a test. An explosive canister of 12-m length and 3-m diameter may be placed inside the cavity.

- *Satellite hole* - means any drill-hole, shaft, adit, or tunnel in which sensing elements, cables, and transducers are installed by the Verifying Party for the purpose of making hydrodynamic measurements. Standard tests use only one satellite hole, while non-standard tests can use up to three satellite holes.

The yield of both standard and non-standard configurations is verified by the Hydrodynamic Yield Measurement Method.

- *Hydrodynamic Yield Measurement Method* - the method whereby the yield of a test is derived from on-site, direct measurement of the properties of the shock wave as a function of time during the hydrodynamic phase of the ground motion produced by the test.

For standard tests, which are required to be essentially fully tamped outside of the explosive canister, the measurement of TOA of the shock wave at locations along a single satellite hole is sufficient for yield verification. For standard tests, the U.S. uses a measurement system consisting of a cable and associated electrical systems called Continuous Reflectrometry for Radius Time Experiment (CORRTEX). CORRTEX measures the time when the cable crushes at numerous locations along the cable.[2]

For non-standard tests, CORRTEX measurements *plus* other measurements, as follows, of the shock wave are made:

- Gage Measurements:
  - Peak stress
  - Peak particle velocity
  - Shock velocity

- Cable TOA Measurements:
  - CORRTEX
  - Additional high resolution measurements
  - Shock velocity derived from TOA measurements

Because CORRTEX *plus* other measurements are used, the method of yield verification for non-standard tests has been termed HYDRO-PLUS by the U.S. nuclear weapons testing community.

In Section 2, this paper describes why HYDRO-PLUS is required for non-standard tests. Section 3 provides a very brief overview of the HYDRO-PLUS methodology and the four technical areas in which activities are conducted. The following four sections briefly describe the activities that are conducted in the four technical areas of the HYDRO-PLUS methodology. Section 8 describes how the information collected from these activities is used to provide yield verification.

Section 9 describes recent HYDRO-PLUS team exercises that are essential for maintaining and improving the HYDRO-PLUS technologies and their integrated conduct. Section 10 describes possible future trends in HYDRO-PLUS technologies.

SECTION 2
WHY HYDRO-PLUS IS REQUIRED FOR NON-STANDARD TESTS

TOA data alone are used for yield verification only within the regime where the shock velocity is changing significantly with respect to distance. This is the technique used for standard tests that are essentially tamped and for which cube root scaling holds. When the ground shock has reached such a low stress regime that it starts to travel at a slowly varying velocity, TOA measurements alone lack the resolution needed for standard hydrodynamic yield verification. The stress regime where TOA measurements lack the resolution for yield verification occurs in soft and hard rocks at below approximately 100 and 200 kbars respectively. For large, non-standard configurations that preclude a significant range for the ground shock to be above about 100 to 200 kbars, TOA measurements alone cannot provide adequate yield verification.

Figures 1 and 2 consider 150 KT tests in hemispherical cavities of different volumes that have been excavated in tuff and granite, respectively. A standard explosive canister has a volume of no more than about 85 m^3 (12-m length and 3-m diameter), and a non-standard cavity can be no larger than 20,000 m^3.

Figures 1 and 2 show *approximate* ranges at which TOA and the additional HYDRO-PLUS measurements (peak stress and peak particle velocity) for yield verification are possible for the different sized cavities. The three regions considered are the following: (1) cavity (light shaded), (2) keep-out (dark shaded) where satellite holes and hydrodynamic measurements are not permitted, and (3) regions where satellite holes can be located (at ranges beyond the light and dark shaded regions).

The light-shaded region represents the radius of the initial hemispherical cavity for different cavity volumes. The initial homogenous pressure level inside a cavity containing 150 KT of energy is indicated. These pressures represent *both* the radiation and hydrodynamic (material) pressures in air with 150 KT of energy. Measurements made outside the cavity would be made at stresses *below* these cavity pressures.

The protocol specifies that "the axis of any satellite hole shall be no less than 6 m from the wall of any drilled or excavated cavity or hole." The dark-shaded regions in Figures 1 and 2 approximately represent the keep-out region beyond the walls of the cavity.

The conservative limit of ranges to which TOA measurements alone can be used for yield verification is indicated in Figures 1 and 2: approximately 100 kbars in tuff and 200 kbars in granite. The regions of good HYDRO-PLUS velocity and stress measurements are also indicated down to about 20 kbars in tuff and down to about 50 kbars in granite. There have been good HYDRO-PLUS measurements made at 15 kbars and below in tuff, and it is expected that good HYDRO-PLUS measurements well below 50 kbars will be possible in granite. However, when these stress regimes are approached, special attention needs to be paid to non-hydrodynamic effects such as strength, joints, precursors, and possible data scatter due to these phenomena.

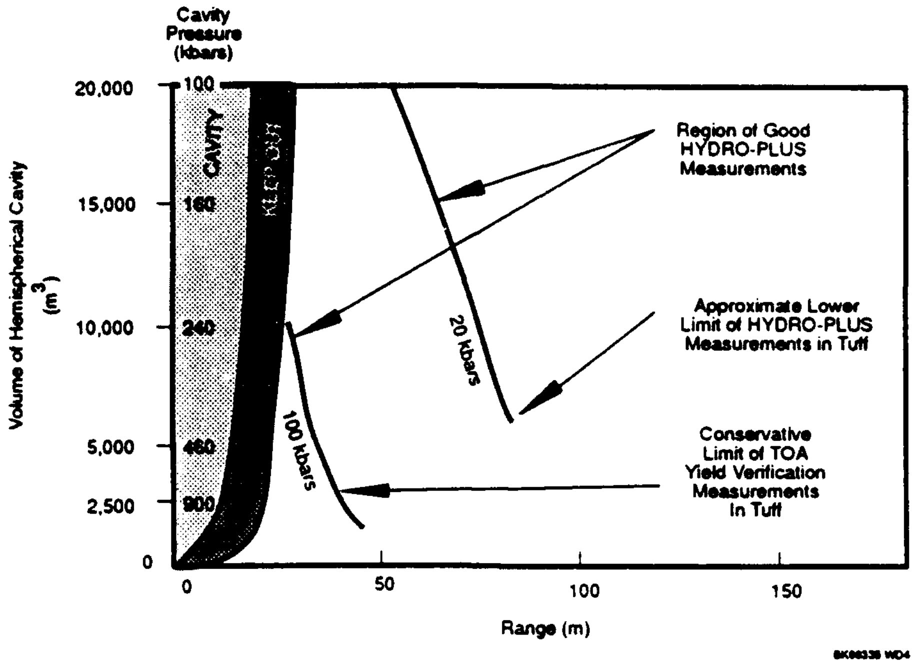

Figure 1. *Ranges of Yield Verification Measurements for a 150 kt Test in Different-Sized Cavities in Tuff*

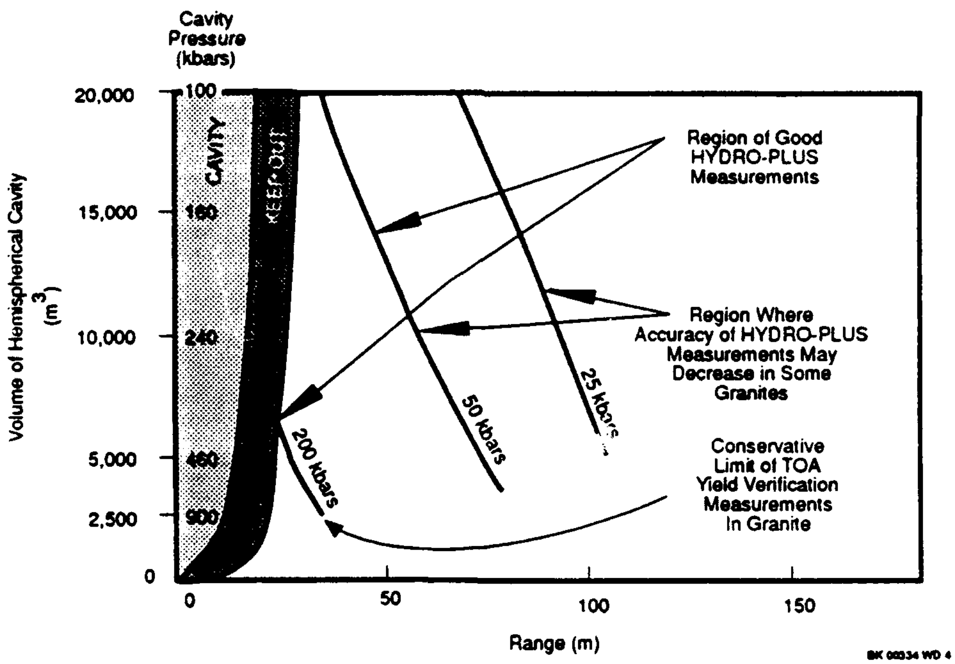

Figure 2. *Ranges of Yield Verification Measurements for a 150 kt Test in Different-Sized Cavities in Granite*

SECTION 3
OVERVIEW OF HYDRO-PLUS METHODOLOGY AND TECHNOLOGIES

In the HYDRO-PLUS methodology, the yield of a non-standard underground nuclear test is verified by comparing calculational results of peak stress, peak particle velocity, and TOA from *calculations of known yields* with *field measurements* of peak stress, peak particle velocity, and TOA *on a test of yield that is unknown to the Verifying Party.* In the HYDRO-PLUS methodology, activities are conducted in the following four principal technical areas:

- Site characterization
- Equation-of-state (EOS) measurements and models
- Calculations
- Field measurements

The activities among these four technical areas as well as activities within each area are synergistic and closely integrated. Results from activities in the first two, site characterization and EOS, are incorporated into *both* calculations and field measurements. The results of calculations and field measurements are compared for yield verification.

The following four sections describe the activities conducted and general procedures followed in each of the technical areas. Activities in the four technical areas of the HYDRO-PLUS methodology have been regularly exercised by the nuclear testing and containment communities of the DoD for over 30 years. During this period, there have been considerable advances in the technologies used in these technical areas; uncertainties associated with their use have been significantly reduced. The following sections and/or subsections provide an indication of the uncertainties currently associated with the technical activities conducted.

SECTION 4
SITE CHARACTERIZATION

The EOS models, calculations, and field measurements areas of HYDRO-PLUS activities all require information about the specific underground test site. Experience has shown that *every underground test site has different site characteristics.* EOS models, calculations, and field measurements all require site-specific information obtained through site characterization activities. These requirements are as follows:[5]

- Geometry of the non-standard configuration, including planned location of nuclear explosive canister.

- Identification and location of significant materials within the hydrodynamic zone. *Significant* (not a protocol term) means of great enough volume or mass to affect calculational predictions of measurements in satellite holes. *The hydrodynamic zone for a nonstandard horizontal test* is defined in the protocol as "a cylindrical region 130 meters in diameter with an axis coaxial with the emplacement hole, extending from a point 15 meters beyond the end of the emplacement hole or access tunnel to a point 65 meters from the center point of the explosive canister in the direction of the entrance to the emplacement hole."

- EOS of significant materials in the hydrodynamic zone and cavity, including materials used to stem satellite holes. EOS data is obtained by using samples from the test site in laboratory experiments. The EOS models are based solely on this laboratory data when previous field data is not available.

- Guidance regarding where to place gages and TOA cables within satellite holes. Regions of geologic discontinuities, major joints or a fault, unstable ground, slumping, etc., should be avoided.

- Characteristics of field materials that could affect gage performance such as unusually high conductivity, frozen rock, etc.

- Outputs from site-specific calculations to provide guidance on gage settings.

- As-built gage and TOA cable locations in satellite holes.

Five types of site characterization activities are conducted to fulfill the above requirements for site-specific information.

- Surveying
- Coring and sampling
- Logging and void detection
- Material properties measurements
- Geologic characterization

The first three are conducted primarily in the field and are often referred to simply as SCL activities. They are conducted in accordance with the protocol by, or under the observation of, the Verifying Party's Designated Personnel at the Testing Party's test site. Material properties measurements are conducted primarily in the laboratory by non-Designated Personnel, and geologic characterization activities may be conducted in both the laboratory and the field. These five activities are briefly described in the following subsections.[5]

4.1 SURVEYING

Surveying in tunnels or cavities where personnel have access can be conducted by classical land survey techniques, which have a high degree of accuracy.[6]

In drill holes, well-established techniques are used to determine location. Depth is determined by the length of the drill string. The other two dimensions can be determined accurately through optical (light) techniques using a luminous target and viewer at different locations within the hole. Dip and direction can be obtained in vertical holes using magnetic and/or gyroscopic techniques. Surveying techniques commonly used for drill holes in tunnels also have a high degree of accuracy, less than approximately ±5 cm, which is about the dimension of a typical calculational zone.

4.2 CORING AND SAMPLING

Coring and sampling activities include the following:

- Identification of the geologic and stemming samples required.
- Acquisition and preservation of samples. (Preservation of *in situ* water content, fractures, and frozen state is important.)
- Shipment to laboratories.
- Preparation of samples for laboratory testing in a manner that preserves *in situ* state as well as possible.

In highly fractured and/or frozen geologies, sample preparation, coring, sampling, and drilling procedures can become quite complicated, working at the limits of current technology.

The key issue for coring and sampling activities is to avoid overlooking something that could be important. In a verification environment, one cannot go back tomorrow to get the missing piece(s).

4.3 LOGGING AND VOID DETECTION

The suite of geophysical log data obtained at a test site could include the following:[5]

- Caliper
- Density, *in situ* bulk

- Epithermal neutron, for water content
- Gravity
- Resistivity/conductivity
- Acoustic
- Video

It is likely that each test site will have specific logging requirements, but bulk density and water content probably will be required at each site. Logging equipment for vertical drill holes is readily available, and typical accuracies for density and water content are both approximately ±5 percent. Logging equipment for horizontal drill holes is currently being further developed.

Although log data for bulk density and water content are less accurate than data from material properties measurements, logs provide a continuous record with respect to location of the property. Log data are correlated with material properties measurements made on laboratory samples obtained at different discrete locations. For satellite holes constructed as a tunnel, most of the continuous geophysical log data will not be obtainable; such data will be obtained only from discrete laboratory samples.

Void detection instrumentation that uses both ground penetrating radar (GPR) and acoustic imaging techniques has been developed. These methods have been chosen for their complementary capabilities and performance characteristics in a variety of geologic regimes. GPR and acoustic surveys will be conducted within the hydrodynamic zone to detect the presence of, determine the location of, and characterize the voids in the surrounding *in situ* rock.

4.4 MATERIAL PROPERTIES MEASUREMENTS

The following laboratory measurements made on samples from the test site are referred to as material property measurements:[7]

- Densities
  - Bulk density
  - Grain density
  - Dry density

From these three densities, percent water by weight, total porosity, saturation, and air voids are calculated.

- Ultrasonic velocities
  - P-wave
  - S-wave

- Mechanical tests; uniaxial static
  - Mean normal stress versus volumetric strain; loading and unloading
  - Stress difference versus confining pressure

The material properties measurements are used along with dynamic gas gun data to develop the EOS models used in the calculations (Section 5).

All of these material properties measurements use well known technologies and techniques and are made with a high degree of accuracy.[7] For instance, for one sample, the accuracy of the three density measurements is within ±0.005 gm/cc. The parameters calculated from these densities have typical uncertainties of the following:[3]

- Water by weight, ±0.5 percent
- Total porosity, ±0.25 percent
- Saturation, ±1.5 to 2 percent
- Air-filled voids, ±0.5 percent

From the perspective of the EOS models, these uncertainties are essentially zero. The spread of results from different samples obtained from different discrete locations within a geologic layer is likely to be considerably larger than the above uncertainties, even within a homogeneous layer. Thus, correlations and established techniques for interval averaging are conducted for point-sample material properties measurements and continuous log data.

Ultrasonic velocity measurements are made with a high degree of accuracy (±1 percent) on a given laboratory sample.[7] The mechanical measurements for stress-strain and strength have uncertainties of less than a few percent.[7]

4.5 GEOLOGIC CHARACTERIZATION

Geologic characterization activities are generally conducted to complement or enhance the data/information acquired through the other four site characterization activities. The objective for conducting them is to ensure that important data is not overlooked and to help reduce uncertainties in the other four activities. Some examples of geologic characterization activities are the following:

- Identification of geologic formations present at the test site and development of geologic cross sections. This is important for obtaining relevant references about the formation, and assessing possible geologic discontinuities within the hydrodynamic zone.

- Crystal structure of geologic materials. This can influence EOS models.

- Rock quality data (RQD) (fractures and joints). This also can influence EOS models.

- Lithologic, mineral, and elemental content. This can affect EOS of geologic materials, opacities used for calculating radiation transport, and gage performance.

SECTION 5
EQUATION-OF-STATE (EOS)

5.1 OPACITY MODELS

For those non-standard test configurations where the explosive canister is inside a cavity (for instance a large air-filled hemispherical cavity or a large nuclear shock tube), radiation hydrodynamic calculations may be warranted. In such cases, opacity EOS models are required by the calculations.

The Verifying Party does not have access to information regarding materials within the explosive canister. However, within or near the walls of the cavity, samples can be obtained of the geologic and/or other materials that would be influenced by radiation phenomenology. Measurements to determine the elemental content of these materials can be made with standard techniques, which have a high degree of accuracy. To obtain opacity models for each material considered in the radiation portion of the calculations, the percentages of elements for each material are used in opacity codes that have been developed by DOE laboratories.

5.2 HYDRODYNAMIC/SOLID MODELS

To develop a hydrodynamic/solid EOS model for a material, four data sets may be used:

Data Set 1 - Site Characterization

- Geologic Characterization - type of rock (or stemming material) for reference to relevant data bases of similar rock types; mineralogy; crystal structure; fracture frequency and character

- Material properties measurements - bulk, grain, and dry densities and calculated parameters: water by weight, total porosity, saturation, and air-filled voids; ultra-sonic velocities; static stress-strain and strength

Data Set 2 - Hugoniot Loading From Laboratory Measurements

- Pressure versus ratio of specific volume at pressure to initial specific volume
- Shock velocity versus particle velocity
- Pressure versus particle velocity

Data Set 3 - Release Adiabats From Laboratory Measurements

- Unloading paths from different Hugoniot states.

Data Set 4 - Hugoniot Data from a Previous Field Test in Same/Similar Rock Type

- Pressure versus ratio of specific volumes
- Shock velocity versus particle velocity
- Pressure versus particle velocity

EOS models are required for each significant material present in the hydrodynamic zone. This includes significant stemming materials and any materials that might have been used to pot the gages. The specific requirements for each EOS depend on the pressure levels to which the material will be exposed during the test. This information will in turn determine how each of the four above sets of data is used and its importance.

For instance, suppose the test configuration is an explosive canister located at the center of a 20,000 m^3 cavity filled with atmospheric air. In accordance with Figures 1 and 2, the maximum pressure to which the surrounding rock will be exposed is less than about 100 kbars. Therefore, laboratory high pressure EOS (HPEOS) data in Data Sets 2 and 3 for pressures much above 100 kbars would be of little utility. However, Data Set 1 would have more utility at these lower pressures. If the cavity were only 1,000 m^3 and the rock was exposed to pressures as high as 2 Mbars, Data Sets 2 and 3 at high pressures would be important.

Presently, there exists no automated or routine technique for the development of EOS models. The process used in the HYDRO-PLUS methodology is as follows.

A group of EOS modelers reviews the available data and develops independent models. These independently developed models are compared and evaluated based on agreement of all relevant available data from the four data sets. One-dimensional calculational parameter studies of the different models generally are conducted and reviewed by the group of modelers.

Calculational parameter studies consider the sensitivity of the models to different input parameters used in the models, possible ranges of values in the data sets; and possible ranges of parameters for which little or no data exist in the data sets. For instance, the site characterization data set may indicate that for one geologic material, one parameter (such as air-filled voids or water content) may have a range of values rather than a single value. Other features of the models, such as release adiabats, for which only partial data may exist, are also examined.

This process provides for peer review and an assessment of the possible range of uncertainties associated with the models that best match the relevant available data. As experience and data are acquired for a particular rock type, and as Data Set 4 accumulates more data, the differences among the models decrease.

SECTION 6
CALCULATIONS

6.1 GENERAL APPROACH

The numerical codes used for HYDRO-PLUS calculations solve the conservation equations of mass, momentum, and energy by finite difference techniques. These equations are cast in one-dimensional (1-D) spherical, cylindrical, or plane geometries; 2-D cylindrically symmetric or plane geometries, and 3-D. The dimensionality and geometry used depend on the purpose of the calculation and the geometry under consideration. Generally, parametric studies for EOS are conducted in a 1-D spherical geometry. 2-D calculations mainly are used for specific tests with perhaps some 3-D studies to ascertain the importance of possible 3-D effects. 3-D studies mainly are used for complicated geometries that occur in specialized regions such as satellite holes.

The codes that are used for HYDRO-PLUS and the personnel who use these codes have witnessed and taken advantage of the tremendous technical advances in calculational technologies during the past 20 years. These advances have been in both the hardware used to run the codes and to produce visual displays of results as well as in the numerical differencing techniques.

To ensure the codes used by the DNA community represent the technical state-of-the-art, DNA sponsors symposia such as its recent Numerical Methods Symposium. At these symposia, the DNA community has an opportunity to hear about recent research and interact with researchers in the fields of numerical methods, computational hardware, and visualization. The DNA community owns a computer in the Los Alamos National Laboratory (LANL) computer facility and procures resources from this facility. The DNA community, throughout the U.S., is connected to the LANL computers. These mainframe computers are often used for the large and complex HYDRO-PLUS calculations while personal computers (PCs) are used for the smaller calculations.

As in the EOS technical area, the HYDRO-PLUS process for calculations uses several groups of calculators. Again, this process provides for peer review and an assessment of different independent approaches so the best can be chosen. It also provides for an approximate assessment of uncertainties associated with the calculations. The groups of calculators participating on HYDRO-PLUS have each had more than 20 years of experience working on nuclear tests with DNA, and their calculations have been validated by data from numerous nuclear weapons effects tests as well as high-explosive experiments.

6.2 SOME FEATURES OF A HYDRO-PLUS CALCULATION

Figure 3 shows a simplified 2-D calculational grid for a cylindrically symmetric calculation of a hemispherical cavity test. The size of zones actually used in a calculation is much smaller than implied by Figure 3. The size may be about 5 cm on a side and/or adaptive zoning techniques may be used to provide even finer zoning and resolution of the numerical solution in the region of the shock front.

The initial boundary of the non-standard hemispherical cavity, which is obtained from surveying, is specified by specific zones in the grid, as is the planned location of the nuclear explosive canister. The zones identified as representing the nuclear explosive canister initially contain energy and/or emit x-ray energy equivalent to the yield used in the calculation. These zones might use an EOS for iron or other material with a relatively high atomic number. The zones within the cavity and outside of the explosive canister would probably use an EOS for air and might use an opacity EOS model for air.

Figure 3 indicates that three layers of geologic material are being considered. The set of zones associated with each of the three layers uses a different EOS model (refer to Section 5). The initial bulk densities for these geologic layers as well as their locations in the calculational grid are obtained from the site characterization activities described in Section 4.

Figure 3 does not show specific zoning for the three satellite holes in which stemming materials may be quite different from that in layers 1, 2, and 3. There are a number of different ways that the satellite holes and their stemming materials can be handled in the calculations.

The fundamental issue is that the gage measurements are made in the stemming material. To make comparisons of calculations and measurements for yield verification, the calculations can:

(1) *Include* the satellite holes and their stemming materials. In this case, the calculations can be compared directly with the measurements made in the stemming.

(2) *Not include* the satellite holes and their stemming materials, and calculate only the ground shock in the *in situ* geologic rock. In this case, measurements made in the stemming need to be converted to measurements that would have been made at the same location in the *in situ* geologic rock.

(3) *Combine 1 and 2*. In this case, one or two satellite holes would be included in the calculational grid and one or two would not.

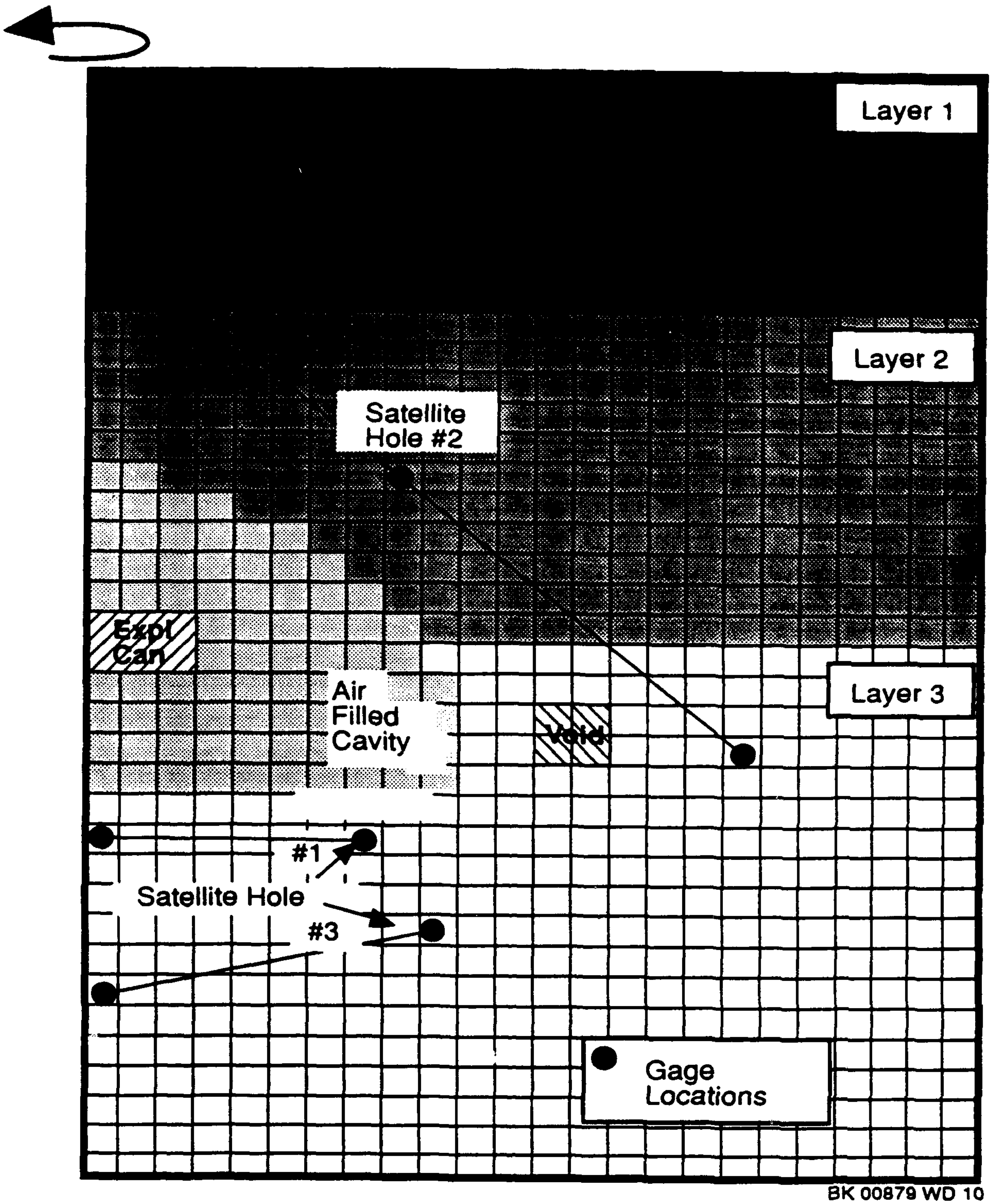

Figure 3. Simplified Example of a 2-D Axi-Symmetric Calculation for One Type of Non-Standard Test Configuration: A Hemispherical Cavity

There are advantages and disadvantages to both including and excluding the satellite holes in the calculations. If a satellite hole is a drill hole, angled across the grid (like satellite holes 2 and 3 in Figure 3), and the hole contains a stemming material similar to the *in situ* rock, it probably would not be included in the calculation. In this case, borehole corrections would be applied to the measurements to convert them to measurements in the *in situ* rock.[4]

If a satellite hole is constructed as a tunnel and contains stemming materials that significantly differed from the geologic layers it intersects, a 3-D calculation that included the tunnel would probably be conducted. In this case, borehole corrections would not need to be made to the measurements.

The above discussion identifies some of the issues that need to be considered when deciding how to set up a calculation for a particular test. Each test will have its own unique issues. In the following discussions, it is assumed that the calculations *do include* the satellite holes and their stemming materials and that the measurements made in stemming can be compared directly with the calculations, i.e., borehole corrections are not required.

Calculational outputs for peak stress, σ, peak particle velocity, U_p, and TOA are saved and edited from the zones that represent gage locations and for all of the zones that represent the satellite holes along which cables are located. If shock velocity, U_s, is available from the calculations, it is saved. Otherwise it is calculated from the Hugoniot relationship:

$$U_s = \sigma/(\rho_o \times U_p) \qquad (1)$$

where ρ_o is the initial density of the material in the calculational zone and σ and U_p are the peak stress and peak particle velocity.

For the planned location of the canister, at least three different calculations at three different yields are conducted as a set. The yields selected are generally at, above, and below the planned yield stated by the Testing Party.

Consistency evaluations are conducted with the calculational outputs. Such evaluations typically consist of plotting the saved calculational outputs in the three EOS formats of

- Peak stress, σ, versus the ratio of specific volumes, $v/v_o = 1 - (U_p/U_s)$
- Shock velocity, U_s, versus peak particle velocity, U_p
- Peak stress, σ, versus peak particle velocity, U_p

These plots are compared with the data sets used to develop the EOS models as well as with the EOS models themselves. Evaluations like these ensure that

- The results are consistent with the input.

- The regions where the shock wave undergoes interaction with a different material or geometry are being calculated properly.

As described in Section 8, to verify the yield of the test, the calculational outputs (from the three or more calculations conducted at three or more yields) are compared with data obtained from the test.

SECTION 7
FIELD MEASUREMENTS

7.1 GAGE MEASUREMENTS

7.1.1 Background Of Gage Development

Field measurements of ground shock from nuclear explosives have been conducted by DNA for more than 30 years. Figure 4 shows years on the x-axis, and the y-axis indicates the regimes of peak stress and peak particle velocity in which ground shock measurements could be made with reasonable accuracy (less than about ±10 to 15 percent). As indicated in Figure 4, after the decision in the 1960s to conduct nuclear testing underground, considerable advances were made in the magnitude of possible ground shock measurements. During the late 1960s and 1970s, the advances essentially ceased. During this period, peak stress measurements of about 5 kbars and below and peak particle velocity measurements of about 0.05 m/s were considered possible.

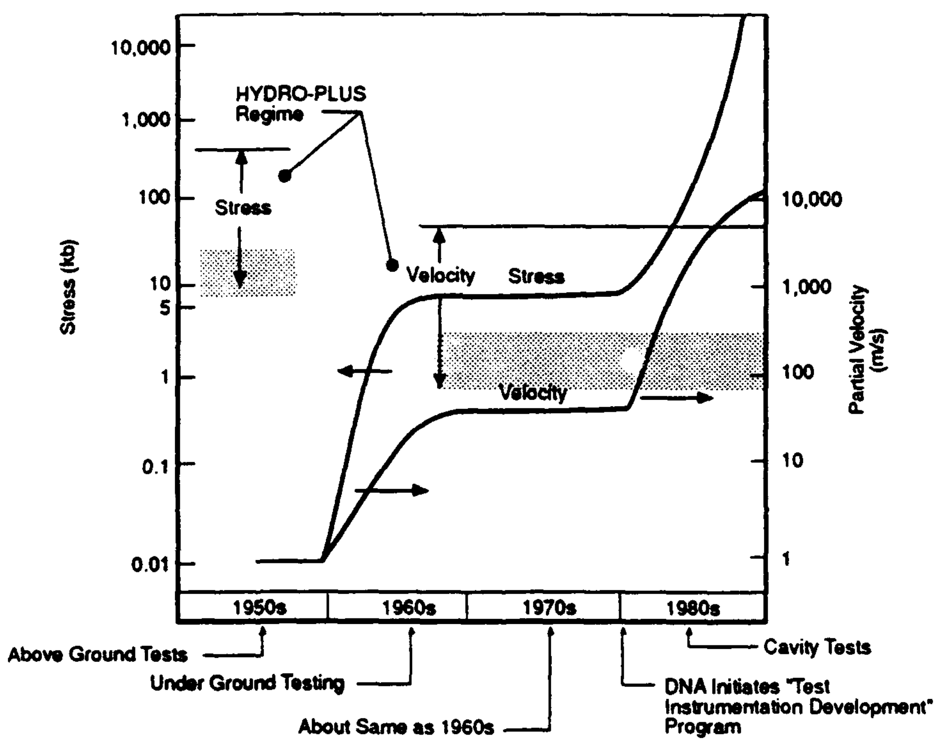

Figure 4. History of Advances in Velocity and Stress Measurements

In 1980, DNA initiated a Test Instrumentation Development Program that resulted in tremendous advances in the regimes where successful measurement of stress and particle velocity could be made. These advances as well as the reliability of collecting such data led DNA to conclude that stress and particle velocity measurements should be made for yield verification of non-standard tests in cases where TOA alone cannot provide a reliable yield.

7.1.2 Gages Used By HYDRO-PLUS

For non-standard tests, the protocol allows up to three satellite holes that may be constructed by the Testing Party as drill holes or tunnels. In each of these satellite holes, up to 6 transducers with no more than "14 cables for information transmission and power supply" can be installed. The total number of cables allowed in each satellite hole is up to 20. HYDRO-PLUS uses 14 cables for transducers; the remaining 6 cables are used for TOA cables as described below.

The six transducers (gages) used by HYDRO-PLUS include three velocity gages and three stress gages in each of the three satellite holes. The velocity gages measure particle velocity as a function of time from which a peak particle velocity at that location, U_p, is obtained. They also measure 2 additional TOAs at discrete locations a few centimeters downstream from the particle velocity versus time measurement. From these TOAs, a shock velocity, U_s, can be obtained. Thus, the velocity gage measures both U_p and U_s at its location. From these two measurements and knowledge of the initial bulk density of the medium in which the measurements are made, ρ_o, a stress can be calculated:

$$\sigma_{velocity} = \rho_o \times U_p \times U_s \tag{2}$$

While it would be desirable to make direct *in situ* measurements of the ground motion, the velocity gages make measurements in the material that surrounds the gage, not in the *in situ* rock; ρ_o is the initial density of this material. This material may be the material used to stem the satellite hole, or it may be a special material which is used to pot the gage to the wall of the satellite hole.

Stress gages measure stress, σ, as a function of time from which a peak stress is obtained. They also obtain a TOA at the location of the gage from the onset of the stress-time signal. These measurements are made in either the stemming material or a special potting material in which the gage is placed.

The velocity and stress gages are installed on an instrumentation string that can be used in satellite holes of *either* drill-hole or tunnel construction. A pair of velocity and stress gages is collocated at three intervals along the string. Their collocation positions are approximately 1/2 m apart, with the velocity gage located closer to the explosive canister (upstream).

As mentioned above, the velocity and stress gages provide measurements in the stemming material (or potting material, which is referred to in the following as simply stemming material). In the following discussion it is assumed the calculations included the geometry of the satellite holes and the materials within them and that the gage measurements can be compared directly with the calculations (refer to Section 6.2).

The following 5 sets of gage data provide a total of 45 gage measurements used to compare with calculations for yield verification.

- U_p at the nine velocity gage locations
- TOA at the nine velocity gage locations

- $\sigma_{velocity}$ at the nine velocity gage locations
- σ at the nine stress gage locations
- TOA at the nine stress gage locations

These measurements in the stemming can be summarized in a table (refer to Table 1). In Table 1, the gage pairs are identified by two numbers. The first refers to satellite hole number one, two, or three; the second (after the hyphen) refers to location of the pair in each satellite hole 1 = closest to explosive canister in this satellite hole, 2 = between 1 and 3, and 3 = farthest from explosive in this satellite hole. Columns two, four, five, six, and seven contain the five sets of measurements cited above. Column three contains the shock velocity data, U_s, that is used in Equation (2) to obtain $\sigma_{velocity}$.

Typical uncertainties associated with the velocity gage measurements are less than ±10 percent. This value is considered to be about a two standard deviation value. Similar typical uncertainties associated with the stress gages are slightly greater, but generally less than ±15 percent.

7.1.3 Consistency Evaluations for the Gage Measurements - a Strength of HYDRO-PLUS

A key strength of the HYDRO-PLUS methodology is that it acquires enough gage data to permit consistency evaluations of the test data. Two types of consistency evaluations are made, Quick-Look and Longer-Term. The Longer-Term evaluations are aimed primarily at improving the HYDRO-PLUS methodology. The Quick-Look evaluations described in this section have been programmed for a PC and can be conducted and plotted within minutes of keying in the field measurements.

The main objectives of Quick-Look consistency evaluations of gage measurements are the following:

- To determine if field measurements are consistent with the EOS models used in the calculations. If they are not, calculations may need to be rerun with improved models before they can be used for accurate yield verification. While a lack of consistency is not expected, it is checked.

- To identify measurements that differ significantly from the main body of data (significant outliers) that could influence portentously yield verification.

- To identify locations of possibly faulty stemming or emplacement procedures.

- To identify issues that may require special consideration for the final yield verification.

Table 1. Summary of 45 Gage Measurements

Gage Location	Peak Particle Velocity	Peak *** Stress Calc From Velocities	TOA @ Velocity Gages	Peak Stress	TOA @ Stress Gages
* V1-1					
V1-2					
V1-3					
V2-1					
V2-2					
V2-3					
V3-1					
V3-2					
V3-3					
** S1-1					
S1-2					
S1-3					
S2-1					
S2-2					
S2-3					
S3-1					
S3-2					
S3-3					

* Velocity Gages

** Stress Gages

*** Peak stress calculated from velocities = initial density in the stemming material x peak particle velocity x shock velocity

Quick-Look consistency evaluations are aimed at identifying data that represent *significant* possible outliers. Since it is desirable to conduct yield verification to within an accuracy of approximately ±30 percent, a significant outlier would be one that would give a yield that is more than 30 percent higher or lower than other measurements. In general, this means the outlier would deviate from the other data by more than about ±20 percent.

The value of ±20 percent varies somewhat (by a few percent) depending on rock type and test configuration, but significant outliers will deviate by as much or more than the uncertainties associated with measurements (Section 7.1.2). Experience indicates there is not always a one-to-one correlation between large gage uncertainties assigned by the experimenters and the identified significant outliers. A strength of the HYDRO-PLUS methodology is that it enables an independent assessment of the data.

Consistency evaluations that are conducted include

- Plots of stress (both from the stress gage, σ, and from the velocity gages, $\sigma_{velocity}$) versus range, and particle velocity versus range. Range may be distance from explosive canister, distance along satellite hole, or distance from some arbitrary location. Outliers will fall out-of-line, and/or not be consistent with symmetries associated with satellite holes. (For instance, two satellite holes may be purposefully aligned so that some of their gages would give redundant results.)

- Initial densities of stemming and *in situ* rock are obtained from site characterization activities. These densities can be calculated from the field measurements

$$\rho_o = \sigma/(U_p \times U_s) \tag{3}$$

  where stress gage σ and velocity gage U_p and U_s are used. This evaluation assesses the consistency between velocity and stress gage measurements. Outliers will result in unusually high or low values for ρ_o. However, it is not possible to determine from this evaluation alone whether the stress gage or the velocity gage measurement is suspect.

- EOS plots of measurements of

  - σ and $\sigma_{velocity}$ versus $v/v_o = 1 - (U_p/U_s)$
  - U_s versus U_p
  - σ and $\sigma_{velocity}$ versus U_p

  compared with the EOS model used for that material and data from Data Sets 2 and 4 (see Section 5). Outliers will deviate from the EOS model and Data Sets 2 and 4. Both the velocity gage and stress gage stresses should be used which results in two sets of points. Using the stress gage stress *and* the velocity gage stress provides information regarding which measurement is a high or low outlier.

An outlier generally will be in the same direction in all evaluations, either too high or too low. If there are many outliers and/or they go in different directions in different evaluations, this indicates that the EOS models are not consistent with the data acquired and that the EOS models used in the calculations should be reexamined.

High outliers result in too high a yield, and low outliers in too low of a yield. How outliers should be treated in analyses for yield verification is still under consideration.

7.2 CABLE MEASUREMENTS

In addition to velocity and stress gages, HYDRO-PLUS may place up to four TOA cables in each satellite hole. Two of these cables are CORRTEX cables and two are Frequency Domain Reflectometer (FDR) cables. CORRTEX cables, which are the standard instruments used for hydrodynamic yield determination in standard events, measure the position of the shock front by measuring the location of the crush of the CORRTEX cable. The time between successive interrogations of the length of the CORRTEX cable may be as long as 20 microseconds. For some purposes, such as the determination of the initial center of energy (COE), much better time resolution is required. Such a capability is supplied by the FDR cables which work on a principle of frequency change and can give a time resolution of a fraction of a microsecond.

Initial COE is the term used to describe the apparent location of the explosive energy source. This is determined from accurate information on the location of the first crush of the TOA cables in the several satellite holes. In evaluating the variation of any measured quantity with range, distance from the COE should be considered as an appropriate range.

The TOA cables give a continuous record of TOA along the satellite holes. TOA cables are generally emplaced in the satellite hole on *both* the near and far side of the satellite hole with respect to where the ground shock first arrives. The data obtained are reduced to provide TOAs that correspond to TOAs in the *in situ* material.

The calculations provide a record of TOA for the zones along the satellite hole. By comparing the cable TOA with the TOAs from calculations at three or more yields, a yield can be determined for different locations along the satellite holes. This provides yield as a function of distance along the satellite hole, rather than just yield at gage locations.

Since almost all of the path of a shock wave from the explosive source to any point on a TOA cable is through the rock, the range versus time curves of these cables represent the properties of the *in situ* rock.

The distance versus time records from the TOA cables can be differentiated to evaluate the shock velocity, U_s, in rock. Shock velocities so derived can be used for the following purposes:

- To compare with shock velocities in the stemming material derived from velocity gage TOA data.

- To obtain borehole correction factors if required. Shock velocity in the rock is the only Hugoniot parameter directly measured for the *in situ* rock.

SECTION 8
YIELD VERIFICATION

8.1 YIELD VERIFICATION USING GAGE MEASUREMENTS

Table 2 shows a format for the output from a set of three calculations conducted at three yields. This format is similar to Table 1 for the measurements. The five sets of calculational output associated with each pair of velocity and stress gage measurement locations can be plotted as a function of yield, W. Figure 5 shows an example of these plots.

The points at the three yields in the five plots in Figure 5 were fit with a least squares power law fit. The fits are of the form

$$\sigma = jW^k \qquad U_p = jW^k, \text{ and} \qquad TOA = jW^k. \tag{4}$$

Other fits, such as piece-wise analytic fits for each two points or a polynomial, also could be used. Plots, such as the five in Figure 5, can be developed for each of the nine locations where peak stress and peak particle velocity measurements are made.

The 45 measurements are compared with the 45 plots. This is done by entering the measurement from Table 1 on the y-axis of the appropriate plot in Figure 5 and finding the yield at which that y value intersects the fit. This process can be automated by solving Equations (4) for W

$$W = (\sigma/j)^{1/k} \qquad \text{or} = (U_p/j)^{1/k} \qquad \text{or} = (TOA/j)^{1/k} \tag{5}$$

Other forms of Equations (5) would be obtained for polynomial fits.

The result is 45 yields for the comparison of the 45 measurements with the calculations. It is likely there will be some spread in the resulting yields, i.e., all comparisons will not give *exactly* the same yield. A simple average of the 45 values can be found. Techniques other than the simple average are also used. Such techniques may combine the fits given in Equations (5) to consider different combinations of measurements or all 45 measurements at one time and/or use statistics that consider the uncertainties associated with the gage measurements and the calculational output. Different techniques have different advantages and disadvantages. However, experience to date shows that for any given test, the different techniques all provide an ensemble value for the 45 measurements that is very similar to the simple average.

Table 2. Summary of Calculational Outputs at Gage Locations from Three Calculations at Three Different Yields

Gage Location	Calculations at Yield 1					Calculations at Yield 2					Calculations at Yield 3				
	Peak Particle Velocity	Peak Stress	TOA @ Velocity Gages	Peak Stress	TOA @ Stress Gages	Peak Particle Velocity	Peak Stress	TOA @ Velocity Gages	Peak Stress	TOA @ Stress Gages	Peak Particle Velocity	Peak Stress	TOA @ Velocity Gages	Peak Stress	TOA @ Stress Gages
* V1-1															
V1-2															
V1-3															
V2-1															
V2-2															
V2-3															
V3-1															
V3-2															
V3-3															
** S1-1															
S1-2															
S1-3															
S2-1															
S2-2															
S2-3															
S3-1															
S3-2															
S3-3															

* Velocity Gage Locations
** Stress Gage Locations

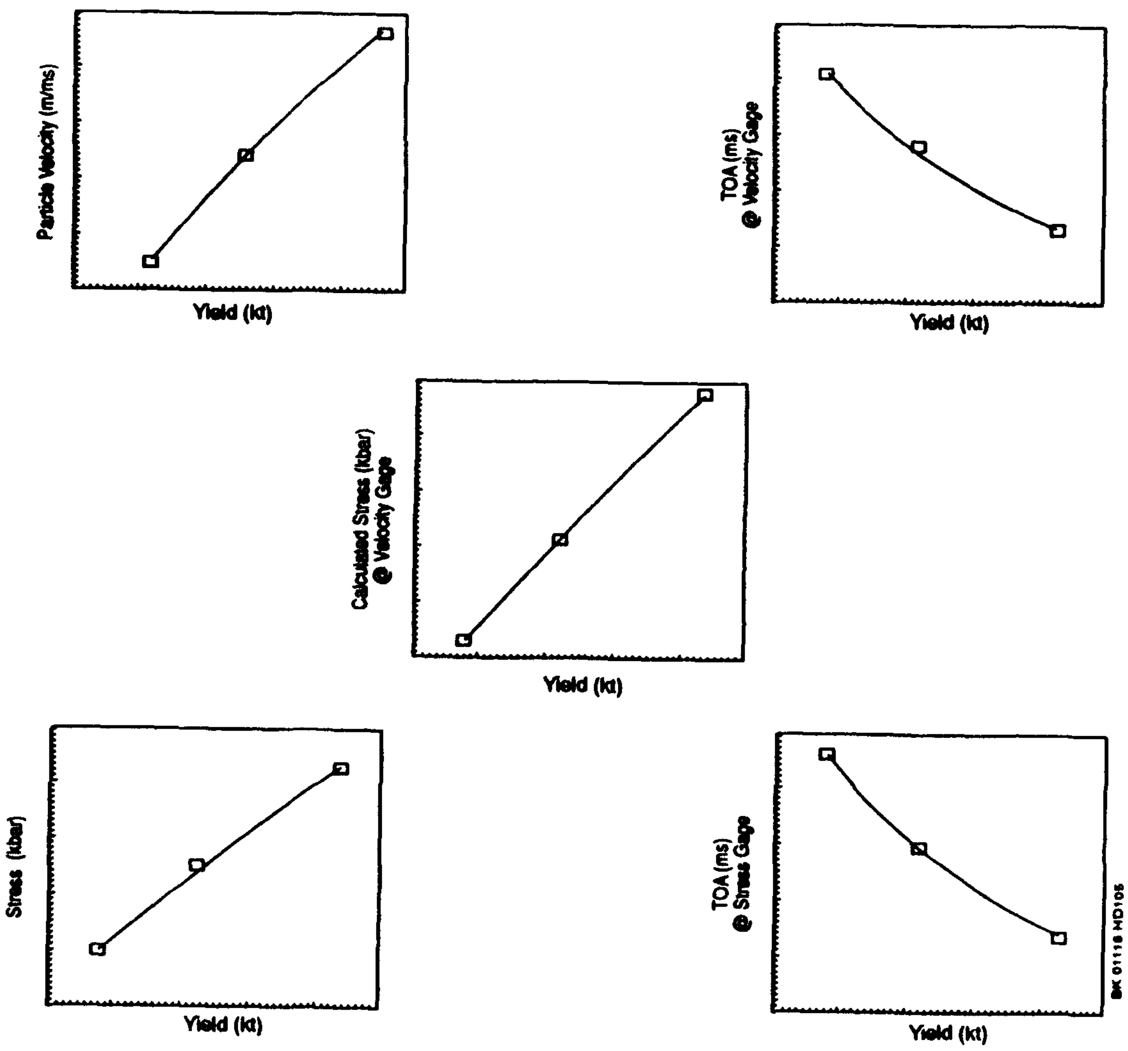

Figure 5. Example Plots of the Five Types of Calculational Outputs Associated with One Pair of Velocity and Stress Gages. Nine Figures Like This are Obtained from the Outputs Given in Table 2

8.2 YIELD INFORMATION FROM CABLE MEASUREMENTS

As indicated in the previous section, TOAs at the various gage locations are a standard output of HYDRO-PLUS calculations. Likewise, calculated TOAs at many locations along the length of the TOA cables can be output. A yield can be determined from each of these locations as described in Section 8.1. The result is yield displayed as a neariy continuous function of position. Such a display can be diagnostically helpful. Standard tests can generally take advantage of simple yield scaling, and in such cases it is possible to find an analytic expression for yield as a function of position. However, simple yield scaling will not generally hold for non-standard tests; and comparison of TOAs with calculations is required.

This process is essentially the CORRTEX method. As was described in Section 2, the CORRTEX method may not be satisfactory below pressures of 100 to 200 kbars, depending on the character of the *in situ* rock. However, the goal of HYDRO-PLUS is to acquire as many and as detailed determinations of yield as possible. Therefore, CORRTEX yields are determined in every deployment of HYDRO-PLUS from both CORRTEX and FDR cables as well as from the peak particle velocity and stress gages.

SECTION 9
HYDRO-PLUS TEAM EXERCISES

To maintain and advance the capabilities required to fulfill its treaty obligations, the DNA has had its HYDRO-PLUS team conduct exercises on some U.S. nuclear tests at the Nevada Test Site (NTS) and in some environments other than the NTS. These exercises are important for training the HYDRO-PLUS team (consisting of *both* Designated Personnel and "folks back home") to work together and communicate under conditions more representative of expected treaty environments than are normal operating conditions.

The HYDRO-PLUS team has conducted exercises on four nuclear tests at the NTS. Three of these were standard tests in vertical drill holes with two, one, and one satellite holes. While the number of satellite holes used in these exercises was fewer than permitted for a non-standard test, the instrumentation used in the satellite holes was the same as described in Section 7. The fourth test on which a HYDRO-PLUS exercise was undertaken was in a non-standard horizontal configuration. Three satellite holes were used on this test, two of which were drill holes and one of which was a tunnel. The instrumentation string described in Section 7 was used in all three.

The HYDRO-PLUS methodology described in the previous sections was conducted on all four of these exercises. The exercises provided many tangible and intangible payoffs for the HYDRO-PLUS methodology and have served to

- Exercise HYDRO-PLUS team in the technical areas of site characterization, EOS measurements and models, calculations, and field measurements

- Provide realistic calculations and field measurements for yield verification analyses

- Train the HYDRO-PLUS team to work together in the field and between the field and laboratories/offices

- Integrate activities in the four technical areas and the yield verification area, and integrate flow of information/data among the areas

- Test improvements in more rapid reduction of gage data and automation of consistency evaluations, yield verification analyses, EOS and calculational procedures, stemming materials, etc.

Test sites in Russia are expected to be very different from NTS. Two of the differences considered by the HYDRO-PLUS team are a much colder and more remote work environment, and the possibility of frozen rock.

To address the colder environment, the HYDRO-PLUS team has conducted exercises at the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) at Hanover, New Hampshire. They have practiced site characterization activities and used equipment in a below-freezing environment. While the team would have preferred to work at a ski resort to test these conditions, they returned from CRREL with some important lessons learned regarding working in a below-freezing environment.

In addressing the possibility of frozen rock, the HYDRO-PLUS team has been developing procedures for drilling, sample acquisition, and transportation. In addition, procedures for using frozen samples in material properties measurements and in gas guns for EOS data are being developed further.

SECTION 10
POSSIBLE FUTURE TRENDS FOR HYDRO-PLUS TECHNOLOGIES

The last year has been so full of unexpected events that any attempt to foresee future trends is an absurd endeavor. Nonetheless, we shall attempt to do so for HYDRO-PLUS yield verification technologies.

- Advances in computer and numerical methods technologies will allow more refined calculations and faster turn-around.

- Advances in hydrodynamic measurements will occur in the areas of even smaller uncertainties in gage measurements, smaller gages, more automated data reduction, improvements in matching stemming materials and *in situ* rocks.

- New rock types will be encountered, and experience will be gained in EOS models, particularly in lower-stress regimes.

- The HYDRO-PLUS methodology will be used more in lower-stress regimes as EOS models for lower-stress regimes become more reliable. Advances in lower-stress regimes could lead to a better definition of source functions for seismic techniques.

- There is a synergistic relationship between HYDRO-PLUS and the successful containment of underground nuclear explosions in that both are concerned with the details of the interaction of the shock wave with the emplacement site. Containment activities involve all four of the main technical areas of HYDRO-PLUS. HYDRO-PLUS technologies will continue to be used and advanced for containment as well as yield verification.

- Conducting multiple tests may prove economically advantageous to the Testing Party as compared to individual tests. This economic advantage could lead to more multiple tests in the future. Multiple tests, as defined in the protocol, would be separated by sufficient distance so that two or more sites could require parallel execution of all four of the HYDRO-PLUS technical areas. A multiple event would require accelerated schedules for accomplishing field and other activities and more personnel support. Previously described technical advances could help to ensure the success of such a crash program.

- Future negotiations of the TTBT could result in a lower threshold. A lower threshold implies that more field measurements would be made at lower stress levels. Because the HYDRO-PLUS methodology can be applied at lower stress levels, a lower threshold would increase the applicability of HYDRO-PLUS over other yield verification methodologies.

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SESSION VI

The Economics of Arms Control

Chairman
J. Milam
BDM International

Conference on Arms Control and Verification Technology
1-4 June 1992
Hospitality House
Williamsburg, Virginia

Balancing Cost and Effectiveness in Arms Control Verification

J. Klare, J. Grotte
Institute for Defense Analysis

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1-4 June 1992
Hospitality House
Williamsburg, Virginia

INTRODUCTION

IDA work on verification issues, 1988-present
- implementation cost estimates
  INF, START, NTT, Bilateral Chemical, CWC, CFE
- measures of effectiveness
  quantitative methodology can be applied to any verification regime

Costs of verification monitoring activities can be substantial
INF > $100 M/year

Some treaties recently entered into force, others imminent

∴ Time is ripe for a broad assessment of verification cost and effectiveness issues

3-4083-2

At the Institute for Defense Analyses, we have been working on two aspects of verification since approximately 1988. The bulk of the work has been in estimating the cost of treaty implementation. We have analyzed INF, START, the nuclear test treaties, the bilateral chemical weapons agreements, the multilateral chemical weapons convention, and the Conventional Forces in Europe Treaty. We have also examined the question of estimating the effectiveness of verification regimes in a quantitative manner.

Motivating this work is the fact that verification monitoring can be expensive. A recent GAO report puts the implementation costs of INF at about $100 million per year, of which monitoring costs run about half. With a number of treaties taking effect or about to, many with similar costs, it is clear that the US is making a substantial investment in arms control monitoring and it is therefore appropriate to look broadly at how those monies are spent and whether our monitoring efforts are performed as efficiently as possible.

PURPOSE AND METHODOLOGY

For future treaties:

Generate some basic rules for structuring monitoring activities to provide effective verification at minimum cost

For new and imminent treaties:

- **identify areas where cost-saving changes could be made without sacrificing effectiveness**

Assessment requires:

- **Identification of objectives for monitoring activities**
- **Examination of alternative approaches for meeting objectives as reflected in different treaties**
- **Estimation of costs by type of activity - what are key drivers?**

Comparative approach

INF, START, CFE, CWC

3-4193-3

Our purpose in this current paper is see if there are any rules for structuring monitoring activities to provide effective verification at minimum cost. The application would be for new treaties and treaties such as START which, while signed, may undergo some changes before entry-into-force. Our process includes identification of monitoring objectives, examination of alternative approaches as reflected in various treaties, and estimation of costs by type of activity to determine what is driving the costs. We have looked across four specific treaties to derive general principles: INF, START, CWC, and CFE.

MONITORING OBJECTIVES

Two basic objectives:

- **Monitor compliance**
- **Detect and document cheating if it occurs**
- **(Deterrence)**

Three generic methods of cheating

- **Failure to declare all TLI as required**
- **Diversion/alteration of declared TLI**
- **Production of new TLI**

3-493-4

Let's examine briefly the objectives of arms control monitoring. Although there are many expressions of this in the official and unofficial literature, there are generally two: first, to satisfy oneself that parties to the treaty are properly observing the provisions of the treaty, which is straightforward enough, and also to detect (and document) cheating if it occurs. Deterrence is frequently mentioned as a third objective, but because it is a subjective condition, it is difficult to measure. We have treated it as an included case.

This second objective is less straightforward and the more difficult to achieve; it is necessary to look a little more closely at how circumvention of treaties can occur. This can happen in three generic ways. First, a party can fail to declare all TLI--treaty limited items--as required to; they can squirrel some away. Second, they can divert or alter declared TLI in such a way that it looks like the items have been destroyed when they have not. Third, new treaty-limited items can be produced and hidden.

MONITORING OBJECTIVES

Each method of cheating is either only possible or significantly easier at certain types of facilities

Method	Types of Facilities Where Possible
Undeclared TLI--Stored or Deployed	Any declared or undeclared facility
Diversion/Alteration of Declared TLI	TLI Infrastructure
Production of new TLI	TLI Production Facilities Potential Production Facilities Undeclared Facilities

Monitoring activities must differentiate between different types of cheating at different types of facilities

3-493-5

We have postulated that each method of circumvention is related to a particular type or types of facilities. Undeclared TLI can be stored, and sometimes deployed, anywhere. If this is a concern, one has to be able to go anywhere to find it. If diversion of declared TLI for purposes of alteration or hiding is the concern, it will have to occur at declared facilities. Production of new TLI for purposes of circumvention can occur at a variety of places. While it is most likely easiest at existing or former production facilities, it can also occur at undeclared facilities and there is no guarantee that this will not happen. In fact, if production facilities are known or easily identified, it is more likely that illegal production will take place elsewhere. Remember this point because it will be recalled when we discuss how to reduce costs.

KEYS TO EFFECTIVE VERIFICATION

Monitoring Regime Must Provide:

1. **High confidence in declared data**
   - **Diversion of declared TLI can occur only at declared facilities**
   - **Validation of declared data and subsequent resampling will provide confidence that**
     - **-- treaty is being complied with**
     - **-- TLI are not diverted**
2. **Access to interior of undeclared facilities**
   - **Illegal storage or production can take place anywhere**
   - **Can confirm illegal activities, but not detect them**
   - **Must be sufficiently intrusive, but not short notice**

From our assumptions about the objectives of monitoring and the types of facilities at which cheating by various means might take place, we believe there are two keys to effective verification. The first is to maintain high confidence in the declared data over time, and the second is to have access to undeclared facilities when concerns arise. Careful monitoring of declared data results in the establishment of a baseline against which compliance can be measured and noncompliance determined. Since, by definition, the only TLI that can be diverted are those that are declared, monitoring declared data should detect any attempts at diversion. At the same time, the discovery of previously unknown TLI can only be evidence of noncompliance if it can be demonstrated that such TLI had not been simply overlooked by the verification regime. Access to suspect facilities is also crucial: since illegal production and storage can take place virtually anywhere, no regime can provide confidence that illegal activities are not taking place without provisions for access to undeclared facilities. It is not enough to suspect a problem, creditable evidence must be found, hence the need for interior access. "Intrusive" is important, "short notice" may not be. To the extent that very short notice is required, we have found that treaty monitoring can be very expensive due to the need to protect sensitive technology and programs.

ELEMENTS OF COST-EFFECTIVE MONITORING REGIME

- Declare all facilities that make up TLI infrastructure
- Validate data at all declared facilities
- Conduct inspections at TLI infrastructure facilities
- Continuously monitor all elimination activities
- Incorporate provisions for inspection of undeclared facilities

3-492-7

The key elements of what we see as cost effective monitoring are, therefore: full declaration of the TLI infrastructure; complete validation of declared data; regular inspections in the TLI infrastructure in sufficient numbers such that, over time, confidence is gained that no TLI are being diverted; thorough monitoring of all elimination procedures, because elimination removes TLI from further scrutiny; and finally, provisions for inspection of undeclared facilities.

DATA DECLARATION REQUIREMENTS

Critical part of effective verification:

- **Basis of comparison by which compliance or violations are determined**
- **Increased risks for cheating nations**
  - **Black and white nature**
  - **Discovery more likely at declared facilities**
  - **Degraded quality and reliability of illegal TLI if maintained at undeclared sites**

2-492-6

Now we'll begin to look more closely at the four treaties under discussion. Data declaration is not always given its due but it is the basis of all subsequent monitoring activities and is the basis for determining violations. Once it is agreed upon, circumvention becomes almost black and white, with discovery of problems more likely at declared facilities. Also, if there is to be circumvention, and if the declared facilities are thoroughly inspected, then this circumvention is pushed out of the declared infrastructure, where quality and reliability of illegal TLI will suffer.

DATA DECLARATION REQUIREMENTS (cont.)

Declared Data Category		INF	START	CFE	CWC
TLI	Numbers/Types	Yes	Yes	Yes	Yes
	Technical Characteristics/Drawings	Yes	Yes	Yes	Yes
Facilities	Operating Bases	Yes	Yes	Yes	N/A
	Storage Facilities	Yes	Yes	Yes	Yes
	Support Facilities (Maintenance, Repair)	Yes	Yes	Yes	N/A
	Test and Training	Yes	Yes	Yes	N/A
	Destruction/Conversion	Yes	Yes	Yes	Yes
	Production Facilities	Yes	Yes	No	Yes
	Potential Production Facilities	No	Yes	No	Yes
Total Number of Declared Facilities		164	115*	3679	1150*

* estimated

2-4/92-9

The four treaties we are considering have almost identical data declaration requirements. The main differences have to do with production facilities--INF has no requirement for declaring potential production facilities and CFE has no requirement for declaring potential or actual production facilities at all. The total number of facilities vary widely by treaty. INF declares only 164 facilities, START only a little over 100 facilities (on both sides). CFE declares almost 3700 objects of verification (OOVs) while the CWC may end up with almost 1200 facilities, depending on what one assumes about the number of Schedule 2 facilities. As we will see, the cost of monitoring a treaty may not be highly correlated with the number of facilities.

GENERIC TYPES OF INSPECTIONS

1. **Data Validation**
   Provide baseline for comparison with data collected in the future
2. **Monitoring TLI-related facilities**
   Verify consistency of data
   Detect diversion of declared TLI or illicit support of undeclared TLI
3. **Monitoring TLI Elimination**
   Verify that treaty-mandated procedures are implemented correctly and that TLI are in fact destroyed
   Detect diversion of declared TLI
4. **Monitoring TLI Production Facilities**
   Detect illegal production of TLI
5. **Monitoring Potential Production Facilities**
   Detect illegal production of TLI
6. **Monitoring Undeclared Facilities**
   Confirm clandestine production or storage of undeclared TLI detected via other means (e.g., NTM, intelligence)

2-492-10

The inspections incorporated in these treaties can be divided into six generic types. These are data validation, to provide the baseline for future comparisons, regular monitoring of TLI-related facilities (quota), monitoring of TLI elimination, monitoring of production facilities, monitoring of potential production facilities, and monitoring of undeclared facilities.

INSPECTION TYPES BY TREATY

Inspection Type	INF	START	CFE	CWC
Data Declaration and Validation	Baseline	Baseline Validation Technical Exhibitions	Baseline	Initial
TLI-Related Facilities	Quota Closeout	Data Update RV/OSI Close-out Formerly-declared New Facilities New System Exhibitions Post-dispersal	Declared site	Routine
TLI Elimination	Conversion/ Elimination	Conversion/ Elimination	Reduction	Destruction
TLI Production	--	PPCM	--	Closure Routine
Potential TLI Production	PPCM	Mandatory SSI	--	Routine
Undeclared Facilities	--	Special Right of Access Visits	Challenge	Challenge

3-492-11

This display indicates how the generic inspection types map into the inspections named in treaty texts.

MONITORING ACTIVITY COSTS

General Cost Factors

NTM: not included

Manpower: inspectors, escorts, linguists, air crews, administration and support personnel
training, salaries, per diem, transportation
military vs. civilian

Equipment:
- **inspector equipment**
  - **ex. tape measures, scales, sampling equipment**
- **equipment left on site**
  - **ex. seals and tags, flow meters, Cargoscan**
- **support equipment**
  - **ex. DMNS data management system**

Technology

Site Preparation

3-4493-12

Let us turn now to actual costs. The estimates that we will show momentarily do not include costs for National Technical Means. Not only are those costs unknown, but it can be argued that NTM operations are not significantly affected by the verification mission, so that the marginal costs are zero. All costs can be divided into two categories: manpower and equipment. Manpower to conduct inspection, prepare sites, move equipment and provide administrative support. Equipment is of various types: inspector equipment, such as simple measuring equipment carried with inspector teams, equipment left on site such as tags and seals, and support equipment such as data management.

Technology is an important driver of costs. More sophisticated equipment results in high development and procurement costs as well as in more expensive manpower to operate the equipment. The use of civilian personnel rather than military, which can result from the use of high technology, also raises costs.

Site preparation costs are sufficiently important to consider separately. Generally, these costs are low, but at industrial facilities, large costs can sometimes arise from having to reconfigure sensitive facilities or to otherwise protect sensitive or proprietary information. Inspections at industrial facilities can also be very expensive if they require the facility to shut down.

MONITORING ACTIVITY COSTS, BY TREATY

Millions of Dollars

Inspection Type	INF	START	CFE	CWC
Data Declaration and Validation	35	25	4	160
TLI-Related Facilities	170	100	41	74
TLI Elimination	53	120	27	290
TLI Production	--	350	--	130
Potential TLI Production	230	36	--	2500
Undeclared Facilities	--	130	5	37
TOTAL [1]	490	760	77	3200

Assumes a 15-year lifespan for all treaties except INF, which has an agreed 13-year lifespan. All costs are to the U.S. government only; costs to other nations are excluded.

[1] Totals may not add due to rounding.

This slide shows the costs by type of inspection for the four treaties over their lifetimes. Only costs to the US government are shown. These are our estimates and not necessarily official. Note that the highest costs for all treaties other than CFE are for monitoring of production facilities. For START and INF, the costs are high even though only a relatively few sites are monitored because highly expensive continuous monitoring is used. For CWC, the costs arise from having to inspect a large number of Schedule 2 facilities. We have argued that data declaration and validation inspections, as well as elimination inspections are crucial to effective monitoring. Hence, savings cannot be made there. Facility inspections must also be done to continue to monitor declared items although lower quotas are conceivable. Lower quotas, however, will not save a whole lot of money. It is in the production area where savings, if desirable, can be made. Because production can occur at undeclared sites, as we have noted, then it is not evident that focussing this much effort on actual or potential production facilities is worthwhile, when the possibility of declared production facilities exist. We think, therefore, that there is opportunity for savings here.

COST REDUCTION PROPOSAL

Focus on START and CWC

- **INF in late stages of implementation**
- **CFE already reflects minimum - cost approach**

Elements:

- **Monitor declared TLI and the TLI infrastructure on a quota basis**
- **Ensure adequate facility preparation time prior to inspections at undeclared sites**
- **Eliminate current provisions for monitoring production facilities**
  - **-- Treat these facilities as undeclared**

Estimated savings of $3 billion over 15 years

2-4/92-14

Based on this line of reasoning, we see significant opportunities for significant savings for future treaties and perhaps for START and CWC. INF is in its terminal stages and CFE is about as inexpensive as it can be, but there is still time to think about changes to START before ratification and CWC remains up in the air. If these treaties monitor the TLI infrastructure on a quota basis, as is generally planned, ensure adequate facility preparation time prior to undeclared sites, as is now the case for START, but eliminate the intensive provisions for monitoring production and potential production facilities, treating them more or less as undeclared, then, according to our estimates, perhaps $3 billion over the next 15 years can be saved by the US government, and perhaps similar amounts by other governments. I think that these general principles are also true for future treaties, especially for regions and systems where the production base is not well known or easily hidden.

Some Industry Proposals on Verification of a Chemical Weapons Convention

L. Zeftel
Chemical Manufacturers Association Consultant

Prepared for:
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Williamsburg, Virginia

SOME INDUSTRY PROPOSALS ON VERIFICATION OF A CHEMICAL WEAPONS CONVENTION

Leo Zeftel
Consultant, Chemical Manufacturers Association

In June 1991, the Western chemical industry tabled a proposal at the Diplomats/Industry Experts meeting in Geneva on how best to assure signatory states that commercial chemical facilities are in compliance with a Chemical Weapons Convention. That proposal was summed up in two words: ANYTIME, ANYWHERE.

While this was not an original concept devised by the chemical industry, it is important to recognize that this was a giant step forward for an industry that jealously safeguards its intellectual property and confidential business information in the face of increasing global competition in the marketplace for chemicals. This step was not taken lightly and occurred only after several years of evaluation. The industry's conclusion was that if there are going to be inspections of chemical facilities to verify compliance with a treaty, then all facilities must be subject to inspection. Some have argued that certain facilities may be excluded and some facilities should be more subject to inspection than others. The chemical industry does not agree with any proposal for exclusion of any chemical facility from an inspection. If some facilities should be higher on an inspection priority list that will be determined by other factors as the treatv organization gains experience in verification procedures.

Since it is reasonable to ask why the chemical industry has made this open offer which in essence increases the potential for inspections over a wider range of facilities than initially envisioned, it may be in order to examine the background of the chemical industry's relationship to the proposed treaty.

The Arms Control and Disarmament Agency (ACDA) requested the assistance of the Chemical Manufacturers Association (CMA) some fourteen years ago to support the negotiations for a treaty to ban the development, production, storage and use of chemical weapons. The Board of Directors of CMA, which represents over 90% of the chemical production in the United States, established a policy of firm support for this request and industry support has continued since 1978. The resources and knowledge of CMA have been made available to all branches and agencies of the government involved in the chemical weapons issues. CMA's ad hoc Chemical Weapons Work Group not only meets routinely with various government representatives but has also made manufacturing facilities available for informational visits, evaluation of verification techniques and national trial inspections. Visitors have included former U.S.S.R. representatives, as part of the bilateral initiatives, as well as diplomats and consultants from other western countries. CMA-sponsored seminars have been held on such subjects as analytical technology, process monitoring and protection of confidential business information. Workshops have been held on other related subjects as well which are pertinent to the successful implementation of a chemical weapons treaty. U.S. industry is not involved in the production of chemical weapon agents but does make and use a number of dual use chemicals for peaceful civil purposes. Dual use is the terminology which describes those chemicals that can also act as precursors or building blocks for chemical weapon agents. Industry, early on, recognized the enormous task that would be involved in monitoring dual use chemicals on a world-wide basis and initiated a cooperative effort with its counterpart industry organizations in Europe, Japan, Canada and Australia to maximize industry inputs to the treaty negotiators, many of whom had little or no understanding of the size and complexity of their own internal chemical industry let alone the global industry interactions among developed and developing countries. This partnership of industry associations has not only helped the industry to better understand the issues and requests from the negotiators for a treaty, but more importantly has enabled the industry to respond more rapidly and effectively to the technical problems and issues raised during treaty negotiations. Verification of the treaty is one of the key issues for both the negotiators and the industry.

Industry inputs and proposals on verification are based on the nature and size of the chemical industry. Worldwide the chemical industry is large in several ways. It handles billions of tons of chemical materials in thousands of locations many of which have a number of facilities at each location which may be specifically or generally oriented towards a chemical or a process. There are some seventy thousand registered chemicals that are produced annually in quantities of under one ton to over a million tons. Industries which handle chemicals include: automotive, food, textile, pharmaceutical and electronics, to name just a few. Chemical industries may be state owned, privately owned or publicly owned and in global interaction, plants in one country may be owned by companies from another country. The industry employs large numbers of people and affects all of us in many of its forms.

The chemical industry is constantly undergoing change, which certainly affects the relationship between the industry and the treaty. Production capability is changing as improved manufacturing processes are routinely introduced in all parts of the industry. This involves changes in equipment design, materials of construction, precursor raw materials and of course processing parameters. Sophisticated processes are no longer proprietary to the western world. In many countries the technology of the 30's is practiced alongside the leading technology of the 90's. Unfortunately for the treaty, some chemical weapon agents can be produced almost anywhere within the parameters of this range of sophistication.

The industry is also changing due to continued concern for protection of personnel and the environment. These changes, increasing in their application and complexity, affect record-keeping, equipment design, waste generation and disposal, control of emissions and discharge practices, all potentially related to some aspect of verification. Process equipment which handles comparatively safe substances is now designed in the same manner once used for only hazardous an toxic materials. Certain signature materials and practices that formerly served as indicators for chemical weapons now are regarded as common safety features with no relationship to treaty violations.

There are other complexities in the chemical industry that will influence its relationship with the treaty. To name a few briefly would include: production scheduling, storage, shipment and distribution, customer quality demands and electronic data processing.

In addition, the chemical weapons treaty will impose much greater demands on the chemical industry than similar international agreements impose on the nuclear industry. Demands may well include providing: a list of plant locations, data on the production, consumption and processing of chemicals of concern, data on the relationships between schedule chemicals and their end use, import and export data and of course requests for inspection of facilities. Data will be requested by the Secretariat of the Organization from a National Authority for each State Party. The National Authority will involve bureaucracy that will require updated information from each chemical plant in the United States to insure treaty compliance (Similar information will be required from all other countries who are part of the Convention). All of this will require far more resources than those used to monitor the nuclear industry.

The U. S. chemical industry is already regulated by product (EPA, FDA and other government agencies), by process (Federal and State regulations), by concern for worker safety (OSHA) and by environmental concerns on aqueous, air and land emissions (Federal, State and Local regulations). Production and shipment of products also come under the Bureau of Census, the Department of Commerce and the Department of Transportation. Not only is the industry tightly controlled, with all activities thoroughly documented, but industry facilities are subject to inspection by a wide range of agencies. Inspections may be scheduled or unannounced and are mandatory when requested. Thus while it will be easier in some sense for the United States chemical industry to cope with the demands of a treaty, it will still require the commitment of additional industry and government resources to meet the treaty obligations. The picture is much worse if we look at the international chemical industry. Many western countries have similar regulatory requirements or are moving in this direction. However, many developing countries are at the early stages of regulatory development in the areas we have discussed and for them the added burden of meeting treaty reporting and control requirements will be a much more significant demand on their resources.

Thus we are faced with an increasing demand on the resources of the chemical industry to show compliance with the treaty. Verification by inspection increases the demand for added resources, both on industry and also on the Treaty Organization through its Secretariat which will be charged with carrying out the verification measures. The chemical industry must play a major role in all of this or it just will not work in examining its role and its assessment of the most meaningful and efficient use of resources to insure compliance with the treaty, the industry came to the conclusion discussed at the beginning of this paper, namely that a key verification factor has to be the option of inspecting all chemical facilities, Anytime - Anywhere.

Verification, via on-site inspection, will definitely serve as a deterrent to potential violators of a treaty, if the inspection regime is properly crafted, operated and maintained. Inspections (1) can be carried out with minimum intrusion to a commercial chemical facility, (2) will optimize the use of the Secretariat's resources, and (3) will minimize the burden on both the Secretariat and the industry. The problem seems to be in where and how the verification inspections should take place.

Some of the delegates to the Geneva talks are in favor of a narrow definition of where inspections should occur. There is no argument that all stockpiles, production facilities for chemical weapon agents, Schedule I chemicals and any other facility directly related to Schedule 1 chemicals should be inspected. There is also essentially no disagreement that immediate precursors to Schedule 1 agents, namely Schedule 2 chemicals, will also require verification inspections to make certain that the amounts produced, consumed, processed or sold are in agreement with the declarations submitted by a location through its National Authority. Note that many of the Schedule 2 chemicals are dual use materials so that consumption by the producer or by the customer has to be verified to ensure that proliferation is not taking place or contemplated. Where a Schedule 2 chemical has no significant use other than as a precursor for a Schedule 1 material, the production volume should show marked decrease or else a good explanation is in order.

The problem really arises on dealing with Schedule 3 chemicals, precursors further removed from Schedule 1 and made in high volume for many civil purposes and so called other relevant facilities or capable facilities". Proponents for a narrow inspection regime want to verify only the named Schedule 3 chemicals, chemicals containing certain selected elements which are similar to the elements contained in Schedule 1 chemicals and facilities that handle these elements even though they are used to make civil products. Examples would be facilities that make chemicals that contain phosphorus and halogen, phosphorus and sulfur or halogen and sulfur.

Restricting verification inspections to the aforementioned areas would reduce the overall number of facilities subject to verification and would reduce the demand on the resources of the Secretariat by not having to inspect questionable locations which had not declared the handling of chemicals of concern. It would also shield potentially relevant government facilities from inspection.

Of more import to an effective treaty is that a narrow verification regime could allow a potential violator to transfer his activities to a location that would fall outside the narrow regime. Simultaneously and unfairly, the verification program would be concentrated among western chemical industries since the current definition of relevant facilities would cover mainly western plants.

Industry's proposal on the other hand would greatly expand the coverage of the verification regime to all chemical facilities, whether or not they are involved currently in handling chemicals of concern for Schedules 1, 2 or 3. Any facility that deals with chemicals would potentially be subject to a verification inspection. Industry further proposes that verification inspections be qualitative in nature and of limited duration.

A qualitative inspection could be structured for each location to a level that is consistent with the chemicals that are handled and need not expend as many resources if there is no involvement with Schedules 1, 2 or 3 chemicals. A limited duration inspection would not only serve the same purpose but would also help minimize intrusion into the legitimate commercial activities of the inspected site.

I would like to clarify several other points. Relevant or capable facilities is almost a meaningless term in the context of making Schedule 1 chemicals. Any chemical facility that has the most rudimentary equipment can make at least one Schedule 1 material, especially if there is not too much concern about protecting the operating personnel or the environment. Obviously making a more complex Schedule 1 chemical and weaponizing it would require more sophisticated equipment, which becomes a question of time, the time to acquire the equipment and add it to the existing facility. By making all chemical facilities subject to inspections you remove the option of operating freely at a chemical facility that does not fall within the narrow guidelines proposed by some delegates for a verification regime.

Another point relates to the concern that a qualitative inspection of limited duration may fail to discover non-compliance. The answer is that first the inspectors should be well trained in the technology required to make Schedule I materials, second the detection equipment carried by the team should be capable of recognizing small amounts of Schedule 1 chemicals or their signature products and third if there is any question raised during the qualitative inspection which can not be resolved, more intrusive methods can be applied, but only if warranted. This will also minimize the need for challenge inspections since open access to all facilities will enable the Secretariat to rapidly determine that no illegal activity is occurring. Finally, requiring a declaration for all chemical facilities raises the argument that we will not be able to fund the resources necessary to inspect all of these facilities. The answer is that all facilities need not be inspected. Having a minimal declaration and the right to inspect all facilities significantly increases the deterrent value of the treaty. The Secretariat can select those facilities to be inspected based on inputs including the declaration, information from other state parties, a randomness factor and of course available resources.

Furthermore, there is the question of protecting national security activities during a broad verification regime. This can be handled in several different ways: putting threshold limits on the chemicals of concern, limiting the broad regime to commercial facilities whether government, privately or publicly owned and requiring a minimal declaration for government facilities but restricting verification to challenge inspections only if the government facility elects not to accept the proposed qualitative limited duration inspection voluntarily.

Industry's intent in recommending a broad verification regime is to best assure that commercial chemical facilities are not being used for chemical weapons purposes. Chemical weapons are produced and controlled by governments and only challenge inspections will detect violations. The U.S. chemical industry has and continues to cooperate fully with treaty negotiators and has made a number of positive contributions to the Chemical Weapons negotiations, largely because our government has been willing to address industry concerns and recommendations. We feel that the proposal for a broad verification regime can only be beneficial to all parties dedicated to achieving a verifiable Chemical Weapons Convention.

Assessing the Verifiability of Multilateral Arms Control Agreements

S. Black, B. Morel
Carnegie Mellon University

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Williamsburg, Virginia

ASSESSING THE VERIFIABILITY OF MULTILATERAL ARMS CONTROL AGREEMENTS

Stephen Black (412) 268-3006 and Benoit Morel
Carnegie Mellon University

The Chemical Weapons Convention(CWC) is ushering in a new era of multilateral arms control; agreements whose verification requires the ability to monitor intrusively a large industrial sector on a continuing worldwide basis. The verification procedures of these agreements must be thorough enough to inspire confidence and their cost (direct and indirect) held to a minimum. The control of other technologies with military applications may generate similar verification requirements.

The traditional approach to discussing arms control verification tends to be based on the one time efficiency of a lone technology of detection. The performance of the integrated verification architecture as a whole is often ignored. This paper will assess the individual and synergistic role of on-site inspections, national and international intelligence organizations, industry cooperation, and export restrictions, in the multilateral control of a militarily significant technology.

In a further break with tradition we argue that in these increasingly complex regimes a more dynamical methodology is required. Taking the CWC as an example, we examine its enforcement as a dynamical process and show that a time based view of the verification system allows a more accurate discussion of its enforceability. This approach elicits the components of the verification system which are most critical to the treaty's successful implementation.

Arguments over the verifiability of the CWC and its implementability go beyond the control of chemical weapons. As the first in a new line of agreements, the CWC will set the tone for assessment of future regimes. A new view of verification assessment applied to the CWC will not only provide a more accurate appraisal of the prospects for chemical arms control but will also pave the way for other treaties which initially appear just as difficult to enforce.

To attain its goal the CWC must monitor one of the largest manufacturing industries. The utilization of a multicomponent, international, diversified verification architecture is the only effective way to achieve such a monumental task. Further, the integrated architecture must be viewed as a dynamical process so that its evolution can be guided to a more effective state.

The assessment of the CWC with respect to these requirements shows that its verifiability is much greater than some have asserted. Its role as a precedent setting regime should not be taken lightly. The convention will not only attempt to prevent the military use of poisonous chemicals, but will also provide important information needed to develop similar agreements governing other technologies.

Architecture and Dynamics

The military exploitation of chemistry technology, from initial research and development to battlefield use, occurs over a significant time line and produces detectable signals at each phase. A given signal of treaty violation can be detected in a number of ways. An assessment of integrated verification rests on the premise that each of the techniques for detecting a signal are independent; each measuring a different aspect of the same violation event. The CWC is also a multilateral internationally monitored regime. A violator of the CWC must consistently and continually avoid detection by a number of national and international monitoring organizations. At a given instant in time, the integration of these possibilities of detection results in a level of verifiability which is significantly greater than any of the individual detection methods.

If this integrated verification process is dynamically applied over time to the detection of a violation its chance of discovering a treaty breach increases. The signals of illegal activity exist for some period of time. A violator must repeatedly evade detection efforts, thus causing an accumulating chance of discovery.

Also of a dynamic nature is the way in which the CWC will adjust itself over time. Any attempt to monitor a dynamic technology, such as chemical manufacturing, must be evolutionary. To maintain its effectiveness the CWC must continually address questions about its industry impact, inspections techniques, and its scope of control. By both refining its operation and adjusting to new chemical manufacturing and chemical warfare technologies the control regime of the CWC may improve over time.

Viewing implementation of the CWC as a dynamic process also allows a more accurate assessment of the level of verifiability needed for successful enforcement of the treaty. This perspective also illustrates the importance of strong interaction between the components of the enforcement regime.

Integrated Verification Architecture

With the possible exception of importing CW agents in munitions form, the development of a CW capability is not a discrete event. The creation of a chemical manufacturing infrastructure capable of producing CW agent in militarily significant quantities, is a complex and protracted operation.[1] A violating state must build or improve several chemical manufacturing facilities for the production of early precursor compounds. Development operations of this nature produce strong signals in a number of areas (economic, military, ect) which will be detectable for a significant amount of time before the country actually has a CW capability.

The verification regime of the CWC will operate on three levels: monitoring, detection, and inspection. The treaty will establish a continuing worldwide search for violations of the agreement. Once a suspicion has been raised, other assets will be used to assess and localize the possible violation. If there is sufficient cause an on-site inspection will be undertaken to establish the existence of a violation.

These three steps in the verification process involve both the public and private sectors and national and international organizations. Each of the elements of the integrated process suffers from their own limitations and provide unique benefits. A careful examination of these verification processes, with an eye toward their synergistic relationship with other processes, shows the importance of this integrated view. When examined individually, not one of the verification processes would be efficient or effective enough to be relied on by itself. However, when taken as a whole, the CWC verification regime is much more manageable.

In addition to their concerted effectiveness, the elements of the verification process also have differing time dependencies. Some, like the on-site inspection, occur at a discreet point in time while others, like intelligence collection, are continuing processes. Because of these differences some verification processes exploit cumulative detection probabilities more than others. The importance of accumulating detection probability must not be under estimated. Several of the signals produced during a violation have only a small chance of being detected. Unless cumulative probabilities are use these events would seem to be undetectable.

National Intelligence Organizations

The detection and localization of a possible breach is the front line of any effective verification regime and the responsibility of the world's national intelligence agencies. It has been suggested that the convention would benefit from an international intelligence organization. The possibility of adequately developing such a service, complete with high resolution imaging and electronic signal collection satellites, human assets, and a complete

[1] In this context a 100 to 200 ton weaponized stockpile is considered militarily significant. In other applications, like terrorism or unconventional tactical use, as little as one ton could be significant.

expert analysis section, is remote. Not only would such an organization be very costly, it would also be politically unacceptable. It is clearly not in the interest of parties like the U.S. to foster the development of an intelligence organization which would provide the world with a clear view of their activities, without increasing their own intelligence capabilities. The most efficient way to solve the problem of multilateral monitoring and violation detection would be to utilize existing intelligence organizations.

The most realistic solution, and probably adequate, is to expect countries to respond when they are informed of a circumvention. It would be the responsibility of the country detecting the violation to find a way to communicate its findings while protecting its sources. No country could expect to avoid detection of an illegal operation if the assets of the Mossad, CIA, DI6, and other national intelligence agencies were all focusing on them. While these agencies will concentrate their efforts according to their national priorities, there will always be the chance that a violator is being targeted. The possibility that a signatory will suppress evidence of a violation for political reasons does not eliminate the benefit of multilateral monitoring. In fact, by resting verification on a number of intelligence agencies this problem is overcome. It is difficult to imagine a situation in which a violator could be assured that only their allies would learn of their actions.

A number of areas must be monitored in order to verify compliance with the CWC: laboratory scale research and development efforts, technology import and indigenous development, changes in chemical manufacturing infrastructure, and changes in force structure to include chemical combat units. The goal of monitoring these areas is to detect the development of a covert production capacity. Covert production includes the modification of an existing legal civilian/military chemical plant and the construction of a single purpose CW plant. These may initially seem to present two totally different planning requirements, fortunately they are quite similar in terms of their equipment, technology, material, and economic signals.

The planning of collection and analysis operations should pay special attention to the driving factors of circumvention. The notion that chemical weapons are the "poor-mans" atom bomb, should be viewed as one of the largest contributors to CW proliferation. Identifying and targeting potential violators is the first step in detecting a treaty breach.

The development of a CW capability will in most cases significantly involve civilian chemical manufacturers, plant construction contractors, or existing chemical manufacturing companies. These civilian organizations may, in some cases, exist outside the borders of the country in question. Intelligence collection planners will need to direct some assets to key areas of the world civilian chemical manufacturing infrastructure.

With only a few exceptions, intelligence collection for the verification of the CWC does not differ much from the verification of other arms control agreements. New technology, both in remote space sensors and in data analysis methods, will make some aspects of verification data collection more effective. Most changes in the collection process will only be refinements in the existing collection system. To increase the probability of detection of a CWC circumvention collection operations agents should be familiar with the requirements of a CW capable infrastructure, and the associated tell-tail signals that the development of a CW capability will produce.

Of prime importance are the ways in which CW weapon differ from other controlled armament systems. Once produced most CW munitions are not, except on close examination, significantly different from there conventional counterparts. Items which are unusual, spray tanks and bulk storage containers, would likely be avoided to reduce the chance of detection. Further, CW agents are chemical compounds without physical form. They cannot be "seen." When using standard imaging systems only secondary signals are detectable not the agents themselves. For these reasons intelligence collection must focus on detection of circumstantial evidence of a violation.

Human assets are clearly the first line of defense in detecting a treaty violation or preparations for a circumvention. It is at the point of initial planning that a violation first becomes detectable. HumInt will provide both initial data on preparation for, and development of a CW capability. Relevant HumInt data will come from four primary sources: the academic world, civilian chemical industry, military, and economic affairs. Each of these areas will provide information on possible circumvention of the treaty. Signal intelligence and survalince imagery may also provide indications of treaty violations.

The role of the intelligence community is solely to provide early warning of a possible treaty breach. During the monitoring stage of the verification process the question of whether a chemical plant under construction is for fertilizer, pesticides, or nerve agent is irrelevant. The important question is will some country's intelligence organization discover the fact that a plant is being built. Once one of the indicators of an attempt to breach the CWC is detected additional assets can be utilized to determine the legality of the actions. The intelligence services must provide the questions which need to be answered.

No intelligence agency can identify, with 100% accuracy, the existence and purpose of a suspect site. But,when the agency is only required to raise data on possible suspect events their abilities increase significantly. While a high false positive rate increases costs and reduces efficiency it should not be a primary concern at this early stage in the verification process. The data produced by the national intelligence services should be designed to have a low false negative rate without undue concern for the number of false alarms.

Once a suspect event has been detected, and confirmed, this information is passed to the international verification organization. Some have expressed questions about the amount and type of data which will be transmitted to the international organization. Any exchange must not compromise collection sources or methods, and yet must provide enough collateral data to support the allegations. To this end an intelligence agency could utilize an number of sanitizing processes including: back channel or third party communication to disguise the data source, commercial satellite images, or a leak to the nev's media without supporting data.

International Verification Efforts

In addition to national verification, the CWC is supported by a number of international efforts. International export controls, international industry cooperation, and the Organization for the Prohibition of Chemical Weapons will also contribute to the treaty's monitoring regime. These enforcement efforts will not only provide additional early warning of a possible treaty breach, but also increase the difficulty of conducting a deliberate violation.

The enforcement strategy of any technology control treaty must be structured to not just detect violations but to deter them by introducing risk and difficulty to every step in the violation process. By involving a number of nearly independent international processes the CWC will increase the level of deception needed to successfully breach the agreement.

These international control efforts must be included in any assessment of treaty verifiability. Despite the fact that they are not completely verification oriented, they can significantly increase the effectiveness of the treaty. The chance of discovering a violation was the foundation for treaty assessment. In multilateral technology control agreements it is only part of the integrated enforcement effort.

The Role of Export Controls

Export control will be a component of the convention's integrated enforcement mission. Despite recent interest in export control, its implementation is and will remain a primarily national bureaucratic process. In the case of the convention, this bureaucratic process will, for better or worse, play an important role.

The manufacture of chemical weapons does not require truly specialized equipment or totally specific precursors. Denying third world countries all equipment and precursors which have dual use would, in most cases, be tantamount to deny them the right to develop their own chemical industry. Much rides on the specifics of the situation. If a country which has no agriculture wishes to purchase a plant to manufacture organophosphorus pesticides, wants also to purchase equipment resistant to the corrosion of Fluoride and equipment suitable for the manufacture of highly toxic chemicals, one can raise legitimate questions about the propriety of an export licence. A case as clear as this will obviously never occur. Instead export control used as an instrument of enforcement of the CWC could legitimize a bureaucratic hindrance to international trade. An over reliance on export controls could create conditions for bureaucratic tensions inspired by the ever present fear of circumvention or by the use of export controls to defend the economic interests of their country.

That the convention could inspire or legitimize an export control policy harmful to third world economies would be, to say the least, undesirable and unfortunate. Chemistry is important for agriculture and will be an important factor in the economic development of many countries. Furthermore the record of export control as an instrument of non-proliferation is not so good. The failure of the export control policy of the Australian group to prevent Iraq from successfully pursuing its chemical weapon program is evidence of its enforcement limitations.

Despite its flaws and limitations, export control can contribute to the enforcement of the convention, by complicating the task of violators. Also it can generate evidences suggesting a violation of the convention. This evidence has, in a sense, much in common with evidences gathered by national intelligence organizations. The country possessing the evidence has its choice of behaviors. It can choose to share its suspicion or not, prohibit the sale or not, or even make its own enquiry to see whether its suspicion is justified.

As with all other elements of the CWC enforcement regime, export control is not by itself sufficient to maintain a prohibition of chemical weapons. Export controls, and sales monitoring, are targeted specifically at the acquisition of technology and raw materials. These controls are not completely effective, but do provide yet another hurdle over which a violator must jump.

The Role of the World Chemical Industry

Any regime which attempts to control a dual-use technology will involve and impact the industry which profits by the civilian applications of that technology. A discussion of the viability of the CWC must at once address the industry's ability to improve the verifiability of the treaty and the chance that it will hamper successful implementation. The international chemical manufacturing industry is incredibly vast, and their cooperation crucial to the success of the CWC. The industry contribution to a ban of chemical weapons comes in several forms: a contribution of expertise, intelligence on possible violators, and assistance in the evolution of the treaty.

Positive involvement of industry in a technology control regime is in no way guarantied. Their participation must be carefully developed by involving industry representatives from the beginning. Taking industry abilities, concerns, and structures into account will aid in the development of a treaty which functions in their interest. While altruistic behavior will improve the enforceability of a control regime, the only guaranty is that industry will act in what they perceive to be their economic interests. The chemical industry will incur a non-trivial cost from the enforcement regime of the CWC. Yet chemical manufacturers are willing participants in the negotiations because of the realization that, without their help, the costs could be significantly higher. Without this type of positive involvement a darker scenario could arise in which companies actively frustrate enforcement efforts for the sake of short term profits.

Among the contributions of industry is knowledge and expertise about the controlled technology. While a treaty is still under negotiation, industry can provide crucial information about risks to their economic welfare and on acceptable verification processes. The CWC has set positive precedent in this area by involving chemical manufacturing associations for the past fourteen years. This cooperation has provided treaty negotiators with an appreciation of the value of confidential manufacturing and business information, locations for National Trial Inspections, and information on manufacturing process modelling. Information of this nature not only reduces the negative impact of the regime on industry, but also improves its effectiveness.

Industry also provides yet another means of discovery of potential treaty violators. Unless a potential violator has a complete indigenous capability, they will be forced to seek outside assistance in their efforts to develop a military application of a controlled technology. In some cases industry may relate information on suspect customers to the international organization. The industry as a source of information should, of course, not be relied on nor should its value be discounted. Its true that there will always be someone willing to illegally sell a controlled technology, but how is a potential violator to know that they are not approaching the wrong company, or the wrong person in a company. It may actually be beneficial for companies to refrain from making their position known publicly in order to maximize a violator's uncertainty. The industry as a verification element is yet another example of a piece of the integrated verification process, that by itself would be insufficient.

As important as its role in the development of a treaty is the aid of industry in effective regime evolution. Chemical manufacturing is not a static technology.

Developments in process design, waste management, manufacturing efficiency, new products, new manufacturing processes for old products, and process safety continually change the nature of the industry. Any verification process which is not equally dynamic is doomed to long term failure. Only industry representatives can be relied on to provide essential data on evolution of the industry. Without industry assistance verification processes will be quickly out paced by commercial developments.

The International Organization

The crux of the international effort to eliminate chemical weapons will be the organization formed by the Chemical Weapons Convention. The Organization for the Prohibition of Chemical Weapons (OPCW) made up of the Conference of State Parties, Executive Council, and Technical Secretariat will be charged with the implementation of the treaty. Information concerning possible treaty violations will be past to the OPCW along a variety of channels. The sum of this data will be used to guide on-site inspections. The multilateral makeup of the organization allows it to take full advantage of the large number of information sources on possible treaty breaches.

As the investigator of alleged violations the OPCW is the point of integration for all of the individual verification elements. National intelligence, export information, industry suspicions, and other data are all combined to provide the OPCW with an unparalleled ability to detect treaty violations. Because these efforts are continuous the OPCW also benefits from an accumulating probability of detecting a violation. The probability of detecting a regime infraction for the integrated process is higher than any of the individual processes yet it still suffers from the fact that the detected event may be a false alarm.

On-Site Inspections

On-site inspections are the final step in the CWC's enforcement regime. Site investigations which discover violations will provide the final information needed to initiate enforcement responses. The probability of detecting illegal production is a function of the probability of detecting a suspect facility and the probability of accurately assessing that suspicion. On-site inspections are efficient for establishing innocence but not for locating suspect facilities.

To be prosecuted, a treaty violation must first be detected and then be established as true. Thus the probability of detecting a violation is the product of the probabilities of detecting and establishing a violation. While on-site inspections can be designed to maximize their ability to evaluate a particular site, they fail utterly when given the mission of locating suspect facilities. Without collateral information the discovery of an overt CW production facility would be unlikely; like finding a needle in a hay stack. The chance of randomly picking the single correct site out of the thousands of potential choices is remote. The detection of covert manufacturing plant would be impossible. Not only are the detection rates in this type of search low, the cost is extremely large.

The discovery of suspect sites must remain outside the scope of the inspection organization. Random on-site inspections can not hope to efficiently detect illegal production.

Once a questionable facility has been located it is the responsibility of the on-site inspection team to determine the guilt or innocence of the plant. The inspection team should focus its search on evidence whose nonexistence implies innocence, as opposed to items whose existence is required for CW production. Instead of searching for equipment, chemicals, and facilities needed for CWA manufacture, inspectors should look for evidence of past (or current) production.

Because an OSI takes place based on data which has a low chance of missing a violation but also a high chance of false alarm, the inspection must be relied upon to reduce the false alarm rate. The conduct of an inspection based on a presumption of guilt will guide both the facility and the inspectors to behave in the most efficient manner. If the facility can provide evidence, to the inspector's satisfaction, that no violation has taken place then the inspection can be concluded. Likewise, the inspection team by looking specifically for confirmation that the facility is not breaching the treaty addresses the false alarm problem.

Even though it is impossible to completely prove a negative this approach to inspection is still the most effective. If all parties are convinced of the ability of inspectors to detect indications of "non-innocence" then a violating site will feel compelled to take some conspicuous actions. By forcing a guilty site to react to an upcoming inspection in an atypical manner the inspection process has attained its goal. The atypical reaction does not prove guilt, but it does allow a new more vigorous approach to the inspection. Instead of the guilt or innocence of a specific site being at issue, the guilty party must respond to their failure to meet the CWC's inspection requirements. As an indicator of guilt, the only evidence better than refusal of inspection access is the discovery of a chemical weapon agent.

A Dynamic View of Treaty Implementation

An assessment of the verifiability of the CWC, or any technology control agreement, must be viewed as a dynamic system. If the monitored technology is in a constant state of evolution, a successful treaty will have to be just as flexible. Also, a regime based on an enforcement process is directly effected by the evolution of that process. An understanding of these factors, the dynamics of enforcement and technological development, is important to a complete view of the viability of the treaty. The behavior of the control regime over time is just as important as a time independent view of it's ability to detect a violation.

Approaching the control regime of the CWC as a dynamic system in no way implies that the originally negotiated treaty was flawed. The nature of the controlled technology and the structure of the enforcement process require that the convention be capable of retaining its strength by adjustment to a changing world.

The possibility that the CWC will enter into force as a viable regime but over time find itself becoming ineffective is very real. Inability to keep pace with chemical technology has the potential to significantly reduce the treaty's ability to meet its goals. Another potential failure mode is a breakdown in the enforcement process. Such a failure could result in a regime which no longer has the ability to effect state behavior.

A better way to look at regimes, like the CWC, is perhaps as a regulated dynamic system, where a violation triggers a response from the rest of the system. The immediate advantage of this approach is its ability to capture the dynamic character of the convention. The success of the convention depends upon its system of responses to circumventions. The response system must be both fast and efficient enough to deny any benefit to the violator. This requires an significant dynamic coupling between verification and enforcement. To be successful the convention must correspond to a "controllable" system, a system which returns to its equilibrium (i.e., a world without chemical weapons), once perturbed by a violation. In other words, the success of the convention will require more than simply addressing the problems of just one section of the dynamic loop, such as solving technical verification problems. The long term ability of the CWC to meet its objectives may depend more on the regime's capacity to link its various components, than on the strength of those components.

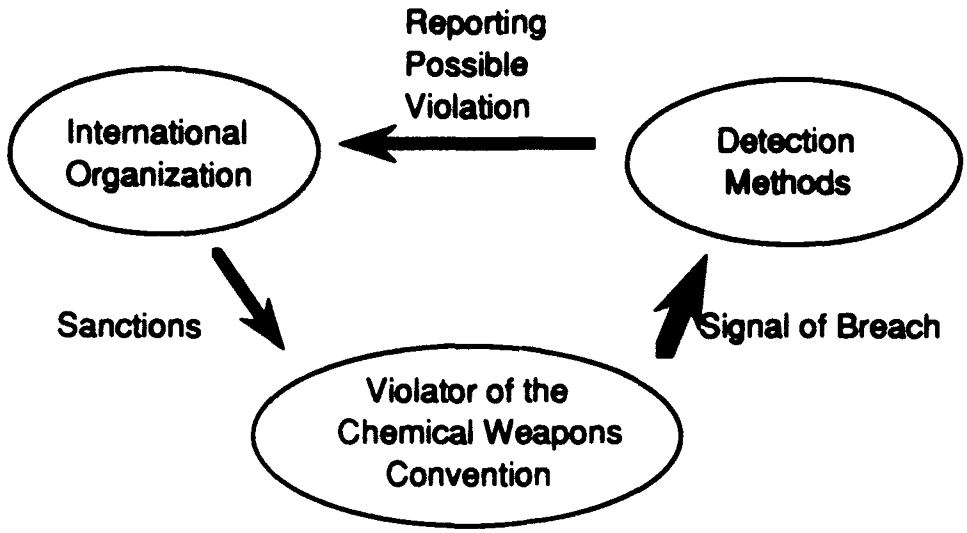

Figure 1. The dynamic control system of the Chemical Weapons Convention

The linkages in the dynamic system shown in figure 1. represent the interactions between the primary components of the treaty regime. Detectable signals of a treaty breach are produced by any violation and detected by the various verification elements described earlier. The second link is the passing of data about a possible violation to the international organization. Finally, the OPCW must take some action to redress an established violation. These three links must, over time, remain strong for the convention to have a lasting impact.

Any actions which weaken the perceived strength of these linkages will endanger the convention's goals. In order to provide an effective deterrent the enforcement process must be perceived as strong and viable. If for example a violation became known to the international community but for some reason no action was taken it would reduce the perceived strength of the sanction linkage. Any failure to fully and aggressively implement the treaty will reduce its effective strength. To maintain its impact the convention must rely on the continuing willingness of national agencies to report data, the successful operation of the international organization, and on the continuing ability of the monitoring systems to detect violations.

The convention must be able to adjust to new developments in a number of areas. Changes in chemical manufacturing technology, new chemical analysis systems, or the development of new weapon agents all require that the convention incorporate new information into its enforcement regime. The international organization must also exhibit an ability to learn from past efforts.

Continual developments in chemical manufacturing systems may remove some indicators of circumvention and add new ones. Improvements in environmental protection may reduce plant emissions, but will provide a new set of suspect equipment. A technical development which eliminates the need for corrosion resistant materials would present similar challenges. By carefully monitoring technologies which impact the goals of the treaty its verifiability can be held constant in the face of industry change.

Constant improvement in chemical analysis systems may help to improve the effectiveness of chemical sampling and analysis inspections. Care must be taken to allow verification laboratories to utilize the most advance equipment available. As new systems become available they must be tested and validated just as the initial systems were. Keeping the verification laboratories on the cutting edge will continually improve the effectiveness of on-site sampling.

Although chemical weapon agent technology is widely regarded as mature, there is no guarantee that a state bent on circumvention will not attempt to develop a new one. The currently scheduled compounds are those that are, or have been, weaponized. The international community must be ready to take steps to add new chemicals to the schedules if it becomes known that they are being militarized. This capability is currently part of the treaty.

Strong organizational memory is of extreme importance to the enforcement regime. The large size of the chemical manufacturing industry, staff turnover, and the complexity of inspections all require a high level of record keeping. Enforcement of the treaty must be subject to a learning curve. Over time the OPCW should improve their effectiveness, and efficiency. The Technical Secretariat, in particular, must have the ability to learn from the past.

Conclusion

In addition to answering questions about the verifiability of the Chemical Weapons Convention this new view of multilateral treaty enforcement helps to set the stage for future technology control agreements. Efforts to control biotechnology, ballistic missile technologies, and the soon to be reviewed Non Proliferation Treaty can benefit from the lessons of the CWC.

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The "Collectivization" of Verification: Exploring the Application of Joint Monitoring Regimes and Multi-Treaty Verification Techniques

B. Murray
Science Applications International Corporation

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The "Collectivization" of Verification: Exploring the Application of Joint Monitoring Regimes and Multi-Treaty Verification Techniques

by Blair L. Murray

On March 24, 1992, the United States signed its thirty-second arms control agreement of the post-World War II period. The agreement, the Treaty on Open Skies, establishes a multilateral confidence-building regime of agreed quotas and permitted zones for overflights to reduce tensions and promote stability.[1] As with the other agreements the United States has concluded in recent years, this treaty provides for a very elaborate and not at all uncomplicated system of procedures and rules to be followed covering everything from registering your proposed flight plan to approving cameras and other equipment on board "Open Skies" flights.

Today the proliferation of conventions, treaties and protocols to limit the uses, abuses or amassing of various weapons is surpassed only by the proliferation of new and advanced weapons and military systems. In addition to the new "Open Skies" accord, there are now thirty-five arms control treaties in force, pending, or being actively negotiated. Some of the older treaties, moveover, such as the Biological and Toxin Weapons Convention and the Nuclear Weapons Non-Proliferation Treaty, are being revisited now, or at least reassessed, to see if further strengthening of some of the treaty's provisions or procedures might not improve the regime.

Verification has been THE central focus of most of the arms control treaty reviews held recently, as well as of all the new agreements concluded in the last decade. As the importance of -- and dependence on -- verification has increased, however, so too has the complexity and cost of verification. In fact, treaties today go well beyond reliance on National Technical Means (NTM) alone. They now also require parties to accept and participate in elaborate, multi-faceted regimes involving declarations, sensing, sampling, detailed reporting, and a wide variety of on-site inspections.

Just as verification has been the central focus in modern arms control, the United States has been a central focus of the verification of the vast percentage of those modern regimes. In

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[1] The multilateral regime established by the Treaty on Open Skies covers all of Europe, Canada, the United States, and the former Soviet Union.

fact, with the single exception of the former Soviet Union, the United States holds the record for being the most over-verified, over-regulated, over-agreed nation on earth. Most countries are party to no more than a dozen or so arms control treaties, most of which contain little to no verification at all. The United States, on the other hand, has signed up to thirty-two arms control arrangements to date. Of those, nearly two-thirds are rigorously monitored bilateral accords, concluded during the Cold War, in an effort to promote international stability and limit or reduce the sources of many of the tensions between the United States and a Soviet Union which no longer exists.

The world is decidedly different now than the one in which all the arms control accords in force today were negotiated. The Iron Curtain has been taken down, exposing as myth or gross overstatement many of the drivers of the East-West arms race. The Warsaw Pact has dissolved, replaced by a disparate collection of new and truly sovereign nations displaying a hitherto unknown openness about their military plans and programs. And the Soviet Union has self-destructed, leaving us without our long-time rival and reason for many of the highly intrusive and expensive verification regimes proposed in the recent past.

The political seachange which occurred nearly overnight and the cold economic realities of today mean that the United States, and most countries, are taking a fresh look at the threats and requirements of the new global environment and making deep cuts in defense and other national security spending. The time may be ripe, therefore, to explore ways to cut as well some of the verification costs associated with arms control proliferation without diminishing compliance confidence. "Collectivizing" verification may be one solution.

What Is It?

"Collectivizing" verification is not an especially unique concept. It is simply combining verification equipment, approaches and other assets and jointly managing monitoring capabilities to meet a wider range of arms control requirements than those of a single treaty or agreement. Nor is it even a very new idea.

The roots of "collectivized" verification can be traced back at least to 1946, and the Baruch Plan, which first suggested that an international authority, rather than individual countries, should have complete responsibility for controlling nuclear energy worldwide and enforcing an international regime to prevent the diversion and use of nuclear materials for weapons purposes. As envisioned, the authority would actually have owned all the fissionable material and controlled its dissemination and use anywhere in the world. It would also have been empowered to carry out on-site inspections of any nuclear facility anywhere it wished. Once a working system was up and operating, the United States would have eliminated all its nuclear weapons and, like everyone else, then subordinated its fissionable material needs and nuclear energy plans to the approval of the international authority.

Of course, the Baruch Plan never came to be. The Soviets simply could not and would not tolerate its unprecedented intrusiveness. Moreover, the Plan was in direct conflict with what the Soviets believed to be their sovereign national right to own and use fissionable nuclear materials as they saw fit, without interference by some outside international authority. The timing, clearly, was wrong. Over the years since, however, numerous countries, including the former Soviet Union, advanced variations on the Baruch Plan theme of centralization in the form of omnibus proposals for International Disarmament Organizations[2] or narrower initiatives calling for an International Satellite Monitoring Agency to facilitate multilateral NTM sharing.[3] While, like the Plan itself, none of the many variations has ever come to be either, the notion has never died that somehow "centralized" verification or "collective" monitoring of a variety of activities could promote broader confidence and stability and play a useful role in arms control.

<u>How Could It Be Applied Today</u>?

At this stage in the evolution of arms control, there are quite a variety of ways in which the "greater" arms control regime of bilateral, multilateral and unilateral treaties and commitments could be simplified and improved. Assets could be shared among treaty regimes. Requirements could be combined or standardized. And overlaps and redundancies could be reduced, if not eliminated altogether. As an adherent to thirty-two accords already, and with more on the way, the United States should have a particular interest in identifying ways to streamline some of its many obligations and action requirements under those treaties. Other countries, too, are apt to be newly inclined to take a look at "collective" verification approaches now, given

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[2] See Swedish statements to the Conference of the Committee on Disarmament dated April 17, 1973 (CCD/PV.601) and July 5, 1973 (CCD/PV.610). Also see Dutch statement dated March 30,1978 (CCD/PV.783) and UN Document A/S-12/22, dated May 27, 1982, transmitting a working paper by the Netherlands "concerning an international disarmament organization".

[3] See French proposal to the first Special Session of the UN General Assembly Devoted to Disarmament, dated May 30, 1978 (A/S-10/AC.1/7).

the changes in the threat and the less than robust economies of the day.

So, what are some of the possibilities the United States and other countries might consider for "collectivizing" verification and streamlining arms control?

"International" Verification Agency:

Or of the oldest ideas, periodically resurrected from year to year, has been establishment of one central agency or organization to handle all the verification requirements associated with arms control. It was a notion first advanced in the early Kennedy-Khrushchev days of arms control, in the context of proposals being pushed then for "general and complete disarmament." The idea was simply that an international verification body might be more acceptable to the Soviets because it would be perceived to be more impartial and less likely to engage in "espionage" activities. Ten years later, following conclusion of a number of multilateral accords, including the Nuclear Non-Proliferation Treaty (NPT), the Seabeds Arms Control Treaty, and the Biological Weapons Convention, the Swedes dusted off the idea of a single organization, in an initiative presented to the Conference of the Committee on Disarmament (CCD) in 1973.

The Swedish Delegation's proposal was to "establish a control organization covering multilateral disarmament treaties <u>in the plural</u>."[4] Sweden was concerned that arms control was evolving into a collection of "<u>ad</u> <u>hoc</u> solutions" where each new agreement was concluded and implemented without "a clear view of all the requirements and opportunities of a coherent control system."[5] Establishing an "International Disarmament Organization (IDO)," Sweden believed, would assure consistency among regimes, provide more efficient channels for receiving and distributing information among various treaties' parties, facilitate implementation of treaties, and set up an international "clearinghouse" of sorts for "knowledge on matters relating to implementation." An IDO would also be able to set the standards or "guidelines" to "assure the fairness and objectivity of verification procedures," but without necessarily conducting investigations itself. Investigations would be carried out by expert sub-groups or appropriate "specialized agencies" as specified in each treaty or with the most obvious competence in the subject.

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[4] See statement by Swedish Representative Alva Myrdal before the Conference of the Committee on Disarmament on April 17, 1973 (CCD/PV.601).

[5] Ibid.

The Netherlands and Japan also advanced proposals for creation of international verification bodies during the 1970s. These proposals, while similar to Sweden's, differed by subordinating the international organ initially to one regime, the chemical weapons arms control regime, which many believed then would be concluded soon. Both acknowledged the possibility of later expanding the scope of responsibility, however; the Netherlands' proposal even specifically suggested the verification body might be used as well in verifying a comprehensive nuclear weapons test ban.

The United Nations, too, as part of its 2 year long study on arms control verification and the United Nations' role in it,[6] has looked at whether it might serve as some sort of central verification clearinghouse for, at least, multilateral regimes. It believed it possessed a special ability to "provide impartial observers and experts" to support regional peace-keeping efforts and strengthen arms control, as it had done in the case of the 1925 Geneva Protocol and investigating the illegal use of chemical weapons in recent conflicts. The United Nations believed it could do more though, too. It envisioned itself providing wide-ranging treaty support services, from collecting and disseminating data, conducting and facilitating research, and offering up specialized expertise and advice, to "operating aircraft overflights and establishing an international or regional satellite monitoring agency utilizing optical, radar and telecommunications satellites."

Recognizing and acknowledging that its "legal authority" to play any role in verification of specific agreements was entirely "dependent" on being granted such authority by the States Parties to the particular agreement, the study emphasized that the United Nations possessed both the "institutional framework" and the "infrastructure" to provide a potentially useful "integrated multilateral approach" to verification. It then went on to suggest a number of possible areas in which this special potential and experience of the United Nations might be applied today and in the future, including to "facilitat[e] conflict resolution efforts, [provide] early warning with regard to emerging crises, or identif[y] confidence- and security-building measures in regions . . . that do not now have [such] arrangements" and "add new monitoring capabilities or help establish far-reaching transparency measures" which could further enhance arms control and promote stability.

While these and similar ideas for centralized verification organs have been discussed and studied from time to time over the years, they have never really stimulated very serious interest of widespread support. The United States, for one, has not been

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[6] See UN Document A/45/372, dated 28 August 1990, "Verification in All Its Aspects: Study on the role of the United Nations in the field of verification."

among the enthusiasts. After its early post-war calls for "general and complete disarmament," the United States moved away from pushing "generic" arms control and resisted omnibus approaches to prohibitions or to treaty monitoring. To be effective, the United States maintained, arms control needed to proceed issue-by-issue, concluding individual agreements on specific and known weapon systems with verification provisions and compliance procedures specially tailored to the weapon systems covered, the threats posed, and the particular parties accepting the constraints of the regime. The United States was also chary of opening up its bilateral arrangements and commitments to international interpretation or otherwise allowing "outsiders" (i.e., countries outside, or not party to, the treaty regime) to interfere in the implementation of its bilateral arms control obligations.

The United States might think about this differently today though. The sheer number of new agreements the United States is party to now, or has pending, augurs for new open-mindedness on this score it would seem. It is also a fact that, even without support for the specific proposals that have been advanced (or perhaps even the awareness of most countries), the United Nations is evolving into a de facto International Disarmament Organization anyway. Unlike the arms control of "olde" when the United States and Soviet Union, or United States, United Kingdom and Soviet Union were the co- or joint depositaries for most regimes, today it is the United Nations that has become the "Depositary of Choice" for new multilateral agreements. Additionally, even for multilateral treaties in which the United Nations has been assigned no specific role or function at all, the United Nations has certain inherent authority.

Today, every time a multilateral treaty reviews its operation and implementation, it first goes to the United Nations General Assembly to pass a resolution to set the review process in motion. It then turns to the United Nations and the Disarmament Affairs Staff within the Secretariat to provide the facilities and administrative support for all the preparatory committee meetings in advance of the review, as well as for the review conference itself. In more than a few instances, the United Nations is called upon to assemble documentation for these reviews and, even occasionally, oversees preparation of substantive reports and assessments for the reviews. When the review is complete, the parties to the treaty then again go to the full United Nations for the General Assembly to pass another resolution acknowledging the review and making its conclusions on the continued operation and integrity of the treaty a part of the United Nations' official record.

Variations on this type of centralized approach could also be adapted and adopted at the national level. This should be of special interest to the United States and Russia, along with its other Commonwealth of Independent States, given the rapid proliferation they have spawned in arms control recently. Two possibilities for "collectivization" of some of the many new bilateral verification activities come most immediately to mind: (1) establishing a single, cross-treaty consultative mechanism, and (2) coordinating inspection plans and procedures for all agreements.

A Single Bilateral Consultative Mechanism:

For the first 25 years of arms control between the United States and Soviet Union -- a period of considerable suspicion and mistrust between the Superpowers -- arms control got by with only a single forum for addressing our bilateral compliance questions and concerns, the Standing Consultative Commission (SCC), established in the early 1970s under SALT I and the Anti-Ballistic Missile (ABM) Treaty. Over the last 4 years, however, during a time of great change and consistently decreasing tensions between the United States and former Soviet Union, there has been a four-fold increase in the bilateral organs established to manage compliance problems with a country that no longer exists.

To safeguard our interests and resolve concerns about intermediate-range nuclear forces, we must go to the Special Verification Commission (JVC). For a question about the threshold of a nuclear test explosion, we are to take it now to the Joint Consultative Commission (JCC). A problem with the new Strategic Arms Reduction Treaty? Then it's off to the Joint Compliance and Inspection Commission (JCIC). And these are all in addition to the consultative commissions, committees, and conferences we must engage to raise a point about any of our many other, multilateral, obligations -- old and new -- from "Open Skies" and CFE[7] to ENMOD[8] and the BWC[9].

While enhancing employment opportunities for senior officers and arms control experts alike, we are running out of acronyms and names for all these consultative mechanisms. Certainly, bilaterally, one could do. Careful management of the agenda for

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[7] The Treaty on Conventional Armed Forces in Europe signed at Paris November 19, 1990, and pending entry into force.

[8] Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, signed at Geneva May 18, 1977, and entered into force January 17, 1980.

[9] The Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, signed at Washington, London, and Moscow, and entered into force March 26, 1975.

meetings of the Single Standing Consultative Commission (SSCC), thorough coordination of positions and presentations in Washington, and proper backstopping and delegation participation by the action experts and policy people responsible for each particular treaty should provide the same level of confidence and cooperation as would any multi-commission arrangement.

A Single Standing Consultative Commission might even enhance the consultative process. For one thing, it would provide consistency in the treatment of problems across treaties. It would also create conditions to spot trends or similarities in the way provisions and obligations are being interpreted and implemented more generally. It should produce certain savings in administrative, travel, and personnel costs, as well, in that the Commission would have sufficient responsibilities from the variety of treaties under its purview to keep it gainfully employed full-time so that it could be permanently staffed and sited in a single location. While such savings might seem of little significance or import to the United States right now, for Russia and the other states inheriting the obligations incurred by the former Soviet Union, these savings could be critical for enabling their continued participation in much of the arms control process over the long-term.

Annual All-Treaty Inspection Plans:

Another verification activity which should now at least be coordinated, if not combined, across our bilateral treaty commitments is on-site inspection. At a minimum, there should be an annual inspection plan and calendar for conducting routine or treaty-specified on-site inspections for all of the bilateral treaties in force between the United States and the former Soviet Union. Better yet, the inspection plan should cover all treaties and schedule any routine or treaty-specified on-site inspections one side might request on the other's territory pursuant to any treaty to which both are party. This would help avoid the possibility (and expense) of having to support multiple on-site inspections at different sites at the same time. Inspection teams, or certainly parts of teams (e.g., linguists, communicators, lawyers, data handlers, etc.), could be cross-trained and used for inspections under any of the bilateral regimes. Multi-purpose equipment (e.g., portable phones, computers, etc.) and transportation needed for the inspections could be shared among the treaties' requirements and used the most efficiently. Eventually, as both sides gain experience and become more comfortable with each others' compliance, they might even be able to agree, through the Single Special Consultative Commission, to combine regimes and accept fewer on-sites inspections of compliance with their bilateral obligations. For example, they might agree to forego all the different approaches to suspect sites, special access requests, and challenge inspections in each of the treaties in favor of a single process to be followed for all bilateral challenges.

Elimination of Dual Coverage:

The inter-relationship of treaties is another area ripe for streamlining in the era of arms control proliferation. As more regimes enter into force and the ever-growing scope of verification activities catches more and more locations, many find themselves in the burdensome position of being subject to multiple inspection visits, or the need, at least, to prepare for such on-sites, under multiple treaties. This dual coverage, of course, increases verification costs overall and requires facilities caught under multiple regimes to be perpetually in inspection stand-by status or a higher state of readiness to receive challenges under all the treaties affecting them. Dual coverage does not, however, provide any commensurate increase in security or compliance confidence.

In these tighter economic times, every penny spent on arms control verification should provide at least another penny's worth of security. If it does not, it should be revisited. The arms control regimes concluded from here on out, therefore, should avoid redundancy and eliminate dual coverage of any locations or facilities not specifically related to the provisions or purposes of the agreement being concluded. It should be a new absolute or sine qua non for arms control -- particularly for the United States and others, like Russia, already subject to so many competing regimes.

The key to eliminating dual coverage is careful drafting. It can be accomplished relatively easily though, particularly for challenge procedures. Challenge provisions can be crafted to apply strictly to facilities, sites or locations within the scope of the particular convention. The term "within the scope of the convention" then would be defined in terms of what it will apply to and what it will not. "Within the scope" should apply to any facility, site or location subject to declaration under the agreement or adjudged by some agreed procedure to be "within the scope" of the particular convention. For the United States and countries similarly subject already to extensive verification under multiple treaty regimes, "within the scope" would not apply to any facility or location already subject to on-site verification under another treaty in force, such as INF or the soon expected START agreement, and registered as applicable. "Within the scope" would also not apply to any undeclared facility specifically excluded from inspection or coverage under registered regimes in force, such as the Nuclear Non-Proliferation Treaty or an NPT party's safeguards agreement with the IAEA.

Coordinated R&D on Multi-Purpose Monitoring Technologies and Equipment

Another new "absolute" for future arms control should be emphasis on developing multi-purpose monitoring technologies and equipment. At a minimum, research and development on verification tools should be coordinated across treaties so that efforts are not duplicated or broader applications missed simply because of specialization and narrowly compartmented perspectives on arms control requirements. R&D on the mechanics of monitoring arms control implementation and compliance during the last decade has been a boom business, not just in the United States, but in the institutes and laboratories of many of our allies as well. Yet little is done to coordinate these activities to ensure the broadest coverage and best combination of expertise and resources possible.

Establishing a regular series of bilateral technical consultations with allied or other countries actively pursuing verification technologies could bear fruit and significantly spur on progress and new directions in verification advances. At a time when considerable interest is being focussed on learning from our inattention to Iraq's activities and devising sensors, tracking systems, and other techniques to safeguard against a recurrence of this type of threat, expanding the pool of experts working on the problem could only improve chances for success. In addition, periodically convening international conferences or smaller regional seminars to review developments in arms control monitoring techniques and verification equipment could also be useful for educating others and stimulating greater acceptance of new equipment, verification approaches and treaty monitoring generally.

Interactive Databases:

Not that long ago, adherence to a treaty required little more than signature and exchange of instruments of ratification. That is not the case for the treaties now. Arms control today is awash in requirements for declarations, data exchanges and detailed inventories of everything from missiles and munitions to the inspectors that countries find acceptable. Some agreements require reporting on activities in progress and others need advance notification of planned events or exercises. Many more want annual summaries of the status of implementation and written explanations for actions taken late. In many instances, arms control regimes could be mutually reinforcing. The declarations and notifications a country makes for one treaty may very well be useful in answering questions or clarifying possible misunderstandings about actions a country is taking under another. It seems worth considering, therefore, whether and, if so, how much of the arms control implementation information and compliance data being amassed might be interchanged and linked through a more integrated system.

The first step toward being able to use data across treaty regimes is standardization. The parties to the treaty regimes participating in the system would need to develop common procedures and formats for submitting the declarations and other data. They would also have to establish guidelines for access to data in the system and controls or passwords to ensure that data, while centrally available in the system, would be shared only with countries with the specific treaty right to the particular data. Of course, countries that wished to permit broader access to their data than just treaty parties could choose to do so. New treaties coming on line would then need to set up their reporting and other data requirements to fit these standardized procedures, formats and access guidelines for the system.

One way to effect such a system would be to set up a single, central repository for collecting and storing all-treaty information. This central repository then would also receive individual country's requests for information or cross-checking of data. Following a request, the repository would obtain release authority from the reporting county, and then share the data with the requestor. An international network of national and international data centers, similar to the network tested recently by the Conference on Disarmament's Group of Scientific Experts (GSE) for the global exchange of seismic data, might be another possibility. Individual country data for countries in the network would be collected and maintained at a national data center. These national data centers would all be linked to the international data center which would be notified whenever new treaty-required reporting or information was available in the national data center. Time sensitive data or requirements would be flagged by each national center and the international data center would be responsible for alerting the appropriate treaty representative assigned to the center.

Assuming a suitable system of access filters and tools to prevent tampering could be developed, it would even be possible, if countries wished, to permit country-to-country direct links to national data centers when questions or concerns arise. Dubbed the "open station" concept during the GSE experiment, direct link access to multiple treaty information would be a real confidence-building boost. Countries could avoid confrontation, quietly clear up ambiguities, and restore their confidence in another party's compliance on their own. They would be more inclined to take care of small misunderstandings rather than wait until minor issues were large enough issue to warrant going to the international center or treaty organization for resolution. It could also significantly cut back the paper shuffle and associated administrative costs since countries would not need to be sending and receiving hardcopy reports for all their various treaty obligations with each other. Countries in the network work could simply enter all their treaty-required reports, notifications and declarations with their national data centers and then electronically alert the international center and fellow parties to its submission and availability. If successful, and if countries are comfortable with the way the network functions, the network could also be expanded beyond notifications and declarations into intelligence sharing and coordinating certain threat assessments.

<u>Centralized Technical and Administrative Support</u>:

One last area where "collectivization" could really pay off for arms control is pooling technical expertise and administrative support. For the last four decades, the ranks of experts and specialists in weapons dismantling, verification systems design, special monitoring techniques and equipment, and on-site inspection have been consistently growing. What the world has now, informally, is an Arms Control Experts Corps of sorts. It may be that, for the future, that is actually the way to go -- nationally and internationally.

The present arrangement is to hire, train and dedicate specialists and support staff and equipment to a single treaty regime. And each new treaty organization starts almost completely from scratch in doing this. For multilateral treaties, it begins with choosing the headquarters site and facility -- typically a highly competitive and hotly debated issue fought out in the final stages of negotiations. Once the headquarters has a home, of course, then the real work begins.

Each treaty regime strikes out for itself to develop its own set of plans, procedures, and basic policy and personnel structures to facilitate the day-to-day operations of the new treaty organization. Inspectors and a whole host of technical and organization support personnel must be recruited. Training programs must be designed and initiated for these inspectors and technical experts, as well as for data handlers, for legal assistants, for administrative support, for communicators, and on and on. Personnel and administrative regulations and policies need to be set and a system established for managing assignments, setting salaries, and evaluating performance and future requirements. Equipment must be procured and, in many instances, as mentioned previously, it must be adapted or tailored, even developed specially, to fill the needs of the new treaty. Similarly, systems for managing data must be designed and set up to be ready to go as soon as a treaty enters into force. A filing cabinet and part-time librarian, once more than adequate, can no longer handle all the information and data (some of it even useful) being generated by treaties today.

Approaching organizing for treaties one-by-one and segregating or restricting expertise and other assets by individual treaty might be fine in a "treaty poor" environment.

In one that is as "treaty rich" as the current one, however, it may make less sense. It certainly costs more -- in terms of efficiency, effectiveness, and dollars spent.

Setting aside politics and the longer-term career interests of treaty negotiators, it is difficult to think of real reasons why most, if not all, of the organizational and administrative activities listed here could not be centralized and shared in some way across the range of treaties. The United States, in fact, is already moving in the direction of centralized management and administration of its many and ever growing verification and treaty maintenance obligations. It uses the On-Site Inspection Agency (OSIA).

While established initially to conduct inspections and other verification-related requirements pursuant to the INF Treaty,[10] OSIA has since had additional responsibilities tasked to it for START[11] and CFE,. It can expect still more now, as well, with the "Open Skies" accord and the upcoming Chemical Weapons Convention. For the United States and its current budgetary constraints, relying on OSIA as a centralized National Authority of sorts is an ideal approach. The infrastructure investment in OSIA's plant facility and administrative and personnel structures is being shared instead of recreated. Procedures are becoming standardized, and simplified, with recurring use. Much of the equipment needed for most on-site inspections is already in-house and ready to go. Procurement systems and standards for budgeting and acquiring new equipment for inspections and treaty monitoring are also already in place. But most importantly, the newer treaties have the benefit of drawing on an inspector corps and technical staff that are already trained and experienced.

An international system that is comparable, but not identical, to the United States's OSIA would work well for implementing verification requirements for multilateral treaties, too. With today's advanced electronics and sophisticated communications capabilities, moreover, functions could be centralized, but not necessarily co-located at a single site or, for that matter, city. One treaty's experts could be tapped for technical advice or special expertise for another treaty. Inspectors and technicians could be cross-trained and allowed to rotate within the system to different treaty regimes. Equipment needs could be coordinated and planned across treaties and

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[10] The Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles, signed at Washington and entered into force June 1, 1988.

[11] The Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Reduction and Limitation of Strategic Offensive Arms, signed at Moscow, July 31, 1991, and pending entry into force.

procurement centralized, with the savings passed on and shared by all the treaties' parties. With carefully agreed rules, certain inspection and monitoring equipment could even be shared among treaties to produce further savings and avoid having equipment sitting idle that could be put to good use in another treaty's inspection.

Conclusion:

In a recent study[12] on future trends in arms control, it was noted that:

> ". .. verification costs will increasingly be the key concern.. . . As U.S. budgets are squeezed more and more each year, Congress will increasingly count verification pennies to be sure we are not spending more over the life of a treaty on disarming a specific threat than we would have spent to retain the capability to counter it. Other countries, too, are likely to do the same.
>
> ". . . cost consciousness will become part of future arms control assessments. Rather than trying new techniques because they are there to be tried, or developing expensive equipment that can monitor very low risk activities, but at high confidence levels, "dollars and sense" will carry the day. Verification for verification's sake will not be a trend for arms control in the future. In tomorrow's security environment, either an on-site visit or a proposed inspection procedure will contribute to compliance confidence in real and tangible terms or it will not make the cut. It is also quite conceivable that this new cost consciousness will be applied retroactively to treaties and regimes already in force. Investing today in beginning to identify possible cost savings and efficiencies to apply now and in the future would certainly be money very well spent."

Combining and "collectivizing" some of our verification activities across treaties would be a good start in that direction.

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[12] See "Trust in Tomorrow's World: Some Thoughts From Where We've Been on Where We Might Be Going with Verification," Chapter VIII, <u>Arms Control for the Post-Cold War World: The New Agenda</u>, SAIC Report prepared for Lawrence Livermore National Laboratory, January 1992.

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